A GROUP OF HICKORIES IN PUTNAM COUNTY, TENN.; PIGNUT IN THE CENTER, SHAGBARKS ON EITHER SIDE.

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HENRY S. GRAVES, Forester.

THE COMMERCIAL HICKORIES.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Forest Service,
Washington, D. C., June 4, 1910.

Sir: I have the honor to transmit herewith a manuscript entitled "Commercial Hickories," by Anton T. Boisen, forest assistant, and J. A. Newlin, engineer in timber tests, and to recommend its publication as Bulletin 80 of the Forest Service.

Very respectfully,

Henry S. Graves, *Forester.*

Hon. James Wilson,
Secretary of Agriculture.

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THE COMMERCIAL HICKORIES.

ECONOMIC IMPORTANCE OF THE HICKORIES.

Of American hardwoods none would be more difficult to replace than hickory in case of a shortage in supply. It is not used in such quantity as white oak, or yellow poplar, or maple, but it is used for a number of special purposes for which it alone is satisfactory. The wood of the hickory is not remarkable for beauty of color or of grain, it shrinks badly in drying, it is not durable in contact with the ground, and it is very liable to attack by insects; on the other hand it is heavy, hard, strong, stiff, and very tough. No other commercial wood, native or foreign, combines these properties to so great a degree. The hickory spoke and rim and the hickory shaft have made possible the American type of spring vehicle with its superior lightness and strength; the hickory handle has helped greatly to make the American ax known all over the world.

The Forest Service has cooperated with the National Hickory Association, an organization of the users of hickory who have foreseen a coming shortage in the supply, and who have united to help prevent it, to study the different species, and to suggest means to produce and maintain the necessary supply.

THE ANNUAL CONSUMPTION.

There are no accurate figures of the annual cut of hickory. The census returns for 1908 show a cut of about 200,000,000 board feet. This is intended to include, however, only the material actually cut and sold as lumber, while much of the hickory cut is not lumber. In 1908 an additional cut, equivalent to about 135,000,000 board feet, was worked up directly into other products, such as spoke billets, handle blanks, and rim strips, difficult to reckon in board feet. This gives a total consumption, excluding fuel, of about 335,000,000 board feet, allowing for all necessary waste. If, however, the unnecessary waste, both in the woods and at the mill, were included, the total amount of hickory consumed would probably be not less than 450,000,000 feet.

INDUSTRIES THAT USE HICKORY.

The vehicle industry uses more hickory than any other, is most dependent upon it, and takes about 65 per cent of the total cut. In America spokes, rims, poles, shafts, singletrees, doubletrees, spring

bars, and axle caps of spring vehicles are all made of hickory; and more than one-half is used for spokes. In Europe oak, ash, and acacia are also used, but they are admittedly inferior, and probably could not be substituted for hickory in American vehicles without a radical alteration of design and a serious loss of lightness and strength, for which the American types are celebrated. About 1 per cent of the annual cut of hickory is used in the manufacture of automobile spokes and wheel rims.

In the manufacture of heavy wagons about 9 per cent of the total output of hickory is used mainly for axles, but also for neck yokes, single and double trees, brake bars, and crossbars. Sometimes it replaces oak for the spokes, although it does not last so long under the trying weather conditions to which wagons are so often exposed.

The tool-handle industry annually uses about 80,000 cords, or 10 per cent of the total cut, of hickory for ax, pick, sledge, hatchet, and other handles which require toughness and strength. Other woods are used for handles, notably hard maple and white oak, but their use is limited and local. The agricultural-implement business uses about 8 per cent of the total cut of hickory for singletrees, doubletrees, axles, crossbars, mower pitmans, eveners, neck yokes, spokes, and rims. The quality demanded is much the same as in heavy wagons, and oak could, in many cases, be used just as well.

Oil wells use about 2 per cent of the hickory output for sucker rods, which must be clear of defects, straight-grained, and from 18 to 35 feet long. Hickory rods, which are superior to others in strength and toughness, were at one time used almost exclusively, but three-fourths of the rods now in use are of iron and the proportion must increase. Wooden rods have the very important advantage over iron that they will float. This advantage is especially important in deep wells where a long string of iron rods is excessively heavy. Material suitable for sucker rods is scarce, however, and wooden rods cost twice as much as iron.

These industries together consume about 95 per cent of the total cut of hickory. The other 5 per cent is used for many special products, such as picker sticks in cotton and silk mills, skewers, golf sticks, whipstocks, ladder rungs, dowel pins, belaying pins, wooden screws, rustic furniture, hames, gymnastic bars, scythe snaths, and quoins.

Hickory is the best American fuel wood and costs about 25 per cent more than any other. It is probable that the greater part of all the hickory cut is used for fuel, and this portion may amount to 1,000,000 cords. Not a little of this, even to-day, is material of the best quality, which should be saved for the spoke and handle maker. In the past tremendous quantities of the finest hickory have been burned.

The use of hickory saplings for hoops has in the past been very important, but is now on the decline. The hickory barrel hoop is recognized as the best wooden hoop, but it is more expensive because it has to be made by hand, and is, therefore, giving way to the patent elm hoop and to iron and wire. The prices of hickory hoops have fallen 20 per cent during the past ten years until 7-foot hoop poles bring only $5 per thousand, cut and delivered, and there is now little profit in them. This is really fortunate, from the point of view of prolonging the hickory supply, because hoop poles require straight, clean saplings from 1 to 2 inches in diameter and from 10 to 15 feet high; this means the destruction of the most promising young growth and the leaving of scrubby and knotty specimens as the basis of the future crop, and has, in fact, secured the survival of the unfit.

EXPORTS.

A great deal of American hickory is used in the vehicle industry abroad. It is exported chiefly in the form of bent rims, spokes, and shafts, but a great many finished wheels and logs are also sent. About 5 or 10 per cent of the annual output is used in this way. In addition, large quantities of hickory, both in finished and unfinished form, are sent to Canada. About 40 per cent of the total output for tool handles is shipped abroad, mainly to Germany, to South Africa, and to Australia.

THE HICKORY SUPPLY.

PRESENT STAND.

Hickory once grew in commercial quantities from Connecticut, New York, and southern Michigan south to Florida and west to Illinois, Missouri, Oklahoma, and eastern Texas. In this region it formed, perhaps, one-fortieth of the total hardwood stand. Measurements of 2,000 acres in the Southern Appalachians, for instance, showed that it formed 5.1 per cent of the trees over 10 inches in diameter. The percentage was greatest in the Ohio and in the lower Mississippi valleys.

The original supply is now approaching exhaustion. East of the Alleghenies and north of the Potomac it has disappeared almost entirely. West of the Alleghenies and north of the Ohio only a few scattered remnants are left, and the bulk of the supply lies south of the Ohio River. Most of the northern manufacturers get their supplies from the South; all of the larger operations are there and competition is very keen. The whole hickory-producing territory has been covered by the timber buyers, and already some of the larger companies are working over their old cuttings, taking material which had been rejected ten or fifteen years ago. In only a few years, probably not more than ten, the conditions of to-day in southern Indiana and Ohio

will be duplicated in the South. The large timber will be scattered and hard to get and the second growth will become the main source of supply.

OWNERSHIP OF LAND.

In the South, as well as in the North, hickory, like oak, ash, and tulip with which it is generally associated, is owned mainly in small holdings. It grows best on fertile soils in a strictly temperate climate, and is most prominent in the agricultural regions of Ohio, Indiana, western Kentucky, and Tennessee. Throughout this region the forests have now, for the most part, been cleared away to make room for agriculture. Hickory is, and probably will continue to be, a tree of the farmer's woodlot, though there are a few large holdings in the river bottoms of the lower Mississippi Valley and in the Southern Appalachians. In all of these, however, the hickory grows in mixture with other species and usually occupies a subordinate position in the stand. None of the larger holdings and, in fact, few of the smaller ones are valuable chiefly for the hickory which they contain. Because of this hickory users have found it impracticable to buy up and hold timber land for the production of hickory.

LUMBERING.

Hickory is cut either by small portable mills, which saw only hickory or hickory and oak, and move on when the supply is exhausted, or in the case of spokes and handles or round bolts, cut by farmers and contractors who rive out the billets in the woods, or ship the round bolts to some central stationary mill.

The portable mill commonly cuts material for rims, poles, and shafts. It requires much skill to work up the hickory properly, so the mills are generally run by men who have made it a life work. These small mills cut the wood into rough strips to be shipped to larger stationary mills for finishing. The cost for logging and lumbering hickory is greater than that for any other common native hardwood. It takes much time and trouble to locate and buy it because it can rarely be secured in large lots; because of the widely scattered supply the mill must be moved a great many times or the logs brought long distances; the wood is hard to cut and heavy to haul, and there is a great amount of waste at the mill—40 per cent or more of the timber that reaches the mill. In addition, rough stock must always be shipped green, and that makes high freight bills. Altogether, it often costs twice as much to get hickory to the factory as it does oak, yet hickory plank, cut in connection with other operations, brings comparatively low prices because it is apt to be cross-grained and has a tendency to check and split when it is not worked up immediately.

Spoke billets are commonly rived. Rived billets are preferred by the spoke makers and bring the best prices, but riving is wasteful. Skilled hands may get as many rived spokes out of a given bolt as could be obtained by sawing, but fewer cuts are taken from the tree and the material which will not make spokes is never utilized, except occasionally for firewood. There is an additional waste because heartwood and birdpecked wood, which would be used if it were at the mill, is generally left in the woods. The price of rived spoke billets in Memphis, Tenn., is $14 per 1,000 billets for the white and $9 for the red. In southern Indiana the prices are $22 and $14. Sawed billets are usually about one-third less. Much waste is avoided when the tree is cut into round bolts of the proper length and these are hauled or shipped to the mill to be sawed. Such bolts bring from $7 to $10 a cord delivered at the mill in the South, and from $10 to $12 in Ohio and Indiana. A cord of hickory will yield about 700 rived spoke billets, or 900 sawed ones, or from 250 to 300 handle blanks.

STUMPAGE PRICES.

Next to black walnut, hickory, according to the census returns, is the most valuable of important American woods. This high value is due in part to the inclusion of the prices of special stock and to the greater cost of lumbering. Stumpage prices, however, are, in most places, still comparatively low, generally about the same as those of oak. In the South the common price is from $2 to $5 per thousand feet. In northern Ohio, according to the location, $15 to $25 is paid, and in eastern Pennsylvania, Maryland, and Virginia, $15 to $35 is common. Oak in these more settled districts brings, perhaps, 30 per cent less.

LOG RULES.

Except where hickory bolts are actually piled and sold, the crudest of methods are used for measuring hickory logs and bolts. Logs over 10 inches in diameter are usually scaled by the well-known Doyle rule, which, in spite of its wide popularity, is one of the most inaccurate of all log rules.[a] It gives values which are too high for large logs and very much too low for small logs. On a conservative estimate based upon a number of mill studies, 10-inch logs show an overrun of as much as 70 per cent in the amount of rough lumber which they will yield; 15-inch logs of 40 per cent; 20-inch logs of 20 per cent; while logs more than 30 inches in diameter show an underrun. This is particularly unfair in the case of hickory because the sizes are usually small, and in an average lot of hickory logs

[a] Forest Service Bulletin 36, "The Woodsman's Handbook;" Forest Service Bulletin 73, "Grades and Amount of Lumber Sawed from Yellow Poplar, Yellow Birch, Sugar Maple, and Beech;" Report of the New Hampshire Forestry Commission for 1905–6.

there will be an overrun of 40 per cent or even more. Sometimes the Scribner rule is used, but even it is unsatisfactory and fails to give the smaller sizes their just values. The greatest injustice exists in the case of short bolts and logs under 10 inches in diameter. Hickory butts under 10 inches in diameter are commonly sold by the linear foot. In northern Ohio they bring 5 cents per linear foot, regardless of diameter. In southern Ohio a sliding scale is commonly used by which the number of cents paid per linear foot is 2 less than the number of inches in the diameter of the log at the small end inside the bark. This is better than taking no account of the diameter, but it is far from correct. For example, a 10-inch log contains nearly three times as much material as a 6-inch log, yet the price is only twice as great; a 12-inch log contains four times as much material as a 6-inch log, but the price is only two and a half times as much.

Handle and spoke bolts are commonly sold by the cord; but since it is often inconvenient to pile the wood in order to measure it, various other devices are resorted to. One common method is to measure the diameters of the 30-inch bolts at the small end inside the bark and add these diameters together until a total of 32 feet is reached. This is called a cord. Two classes are generally made—bolts between 6 and 8 inches in diameter and those over 8 inches. Some difference is made in the price, but it is never enough. In one place, for instance, the first class brought $5 per cord and the second class $7; yet, even if the average diameter of the two classes had been 7 and 9 inches, the ratio should have been 5 to 8. As a matter of fact, the average diameter of the second class was considerably over 9 inches, and the difference should, therefore, be much greater.

In some cases an estimate is made of the number of billets which the bolts contain, and they are bought at so much per thousand.

The result of present methods is that highest values are given to small sizes on the one hand and to the largest on the other, while the very sizes which are most to be desired and which in the future should be most profitable, the logs and bolts from 9 to 15 inches in diameter, are given the lowest values, sometimes by as much as 25 per cent or more.

WASTE.

The amount of merchantable hickory wasted each year may be conservatively estimated at 40 per cent of the total cut. It consists both of waste in the woods and waste at the mill.

The greater waste is in the woods and is due chiefly to unnecessary restrictions against heartwood and birdpecked wood. Millions of feet of good hickory are cut each year and left in the woods because of the presence of a few birdpecks, or the large proportion of heartwood makes it unprofitable to market it. Such waste is

especially great where spoke billets are rived out in the woods and only white billets are taken, because the red billets bring little more than half as much as the white. Another source of waste comes from the discrimination against the wood from the upper cuts of the tree in favor of that from the lower cuts. This is due not alone to the knottier character of the upper logs, but also to the prevalent opinion that the wood is considerably inferior to that from the lower cuts. The practice of cutting high stumps prevalent in the South is also very wasteful. It is claimed that the difficulty of sawing out with the grain makes it unprofitable to cut below the flare of the butt; therefore small trees are generally cut more than a foot above the ground and large trees more than 2 feet. Some firms, however, cut low stumps and consider that the greater width of the sap and the greater toughness of the wood in the butt is a sufficient offset to the difficulty of sawing. If the average stump height—at least 2 feet—were reduced only 8 inches, as would easily be possible, there would be saved as much as 10,000,000 board feet annually on the total cut.

A somewhat unavoidable waste arises from the taking out of special products. The pole and shaft or the sucker-rod makers leave a lot of stuff in the woods which would make good handles or spokes, while the spoke or handle makers use up a great deal of material which should really be put into poles, shafts, rims, or sucker rods. Even where economy is attempted and spoke billets or handle blanks are cut in connection with poles, shafts, or rims, it is often difficult to dispose of the by-product, and it often happens that for lack of a market thousands of feet of hickory are destroyed by insects.

Much of the waste at the mill is due to the discrimination against the heartwood and birdpecked material. Another source is the practice of cutting spoke billets and rim and pole and shaft strips unnecessarily long. This is especially true of spoke billets, which are cut into a uniform length of 30 inches, whereas the spoke lengths range from 18 to 24 inches.

In addition to the waste of merchantable material, in lumbering much promising young growth is used for skids, is swamped out, and is broken by falling trees. This loss is hard to estimate, but it is very great, and will seriously affect the future supply.

THE TREE AND ITS FORMS.

The hickories belong to the same family as the walunts. Botanically they represent a very old form and rank among the earlier hard woods. The genus is now peculiar to North America and is confined almost entirely to the eastern part of the United States, though some species grow in Canada, and in Mexico it is represented

by an indigenous species (*Hicoria mexicana*) and by the pecan and the nutmeg hickory.

The fruit of the hickory is the most unmistakable characteristic of the genus. In general it is much like that of the walnut—a nut with a single two-chambered kernel, each chamber partially separated into two lobes. The shell, however, is smooth on the outside, and the husk, instead of being entire, splits into four segments, usually from the apex to the base, and allows the nut to drop out. In size and shape, and in other ways, the nuts vary greatly in the different species. The nut of the big shellbark is often an inch and a half in diameter and has a thick, hard shell, while that of the bitternut and the water hickory is small, only about ½ inch in diameter, with a thin shell and thin husk. The best known forms are the pecans and the shagbarks, which form important articles of commerce. The big shellbark and the mockernut also produce edible nuts, but those of the bitternut and water hickory are quite astringent.

FIG. 1.—Pecan (*Hicoria pecan*). Twig, natural size; leaf and fruit, one-third natural size.

The leaves are always compound, with three to fifteen leaflets, arranged in opposite pairs, with a single rather larger leaflet at the end. The leaves are arranged alternately on the twigs. This feature offers a ready means of distinguishing the hickories from the ashes, which have opposite leaves. The pith is solid and not chambered as in the walnuts.

The hickories are characterized by a very strong taproot. In no other genus in this country is the taproot developed to a greater extent. (See Pl. III, fig. 1, p. 16.) The size of the taproot varies, however, with the species and with the situation. It has its greatest development in the drought-enduring species and in the drier situations. In wet river bottoms the taproot is not so well developed.

The bark varies greatly and has no single easily distinguishable characteristic common to the genus. The reddish-brown bark of the shagbark scales off in long thin strips, and is so characteristic that it can not be mistaken. (See frontispiece.) The bark of the mockernut is light gray and does not scale off at all. Between these two extremes, there are all degrees of scaliness, and within each species the bark varies so that it alone is not a safe guide in distinguishing the species.

The bud characters divide the hickories into two distinct groups—the true hickories and the pecan hickories. The true hickories are characterized by full, round buds, with many overlapping scales, of which the inner ones are usually hairy. Buds of the pecans are generally thin and narrow and have no overlapping scales, but are covered by two closely fitting ones with a glandular surface. This natural distinction is further borne out by other general characteristics of the two groups. The nuts of the pecan group are generally thin-shelled and thin-husked, the leaves have from 7 to 15 comparatively narrow leaflets, the bark is only moderately scaly, and the wood is comparatively weak and brash. In the true hickories, the nuts are generally hard-shelled and thick-husked, the leaves have from 3 to 9 leaflets, the bark is generally scaly, and the wood is strong, hard, and tough. This group furnishes practically all the hickory wood of commerce.

FIG. 2.—Water hickory (*Hicoria aquatica*). Twig, natural size; leaf and fruit, one-third natural size.

There is still much difference of opinion among botanists as to the number of species. Some botanists distinguish as many as 15. From the forester's standpoint, however, the extremely minute subdivision into species is unnecessary and confusing. The newly distinguished species closely resemble in some characters the older types, so that it is difficult for even trained botanists to tell them apart.

In this publication these more recently described species are treated as varieties and only 8 main types are described; of these, 4 belong in the pecan group and 4 are true hickories.

THE PECAN HICKORIES.

PECAN.

In the pecan group, the true pecan (*Hicoria pecan*) is the most important because of the value of its nuts. The pecan is the largest member of the genus. Sargent records a height of 170 feet with a trunk from 5 to 6 feet in diameter.

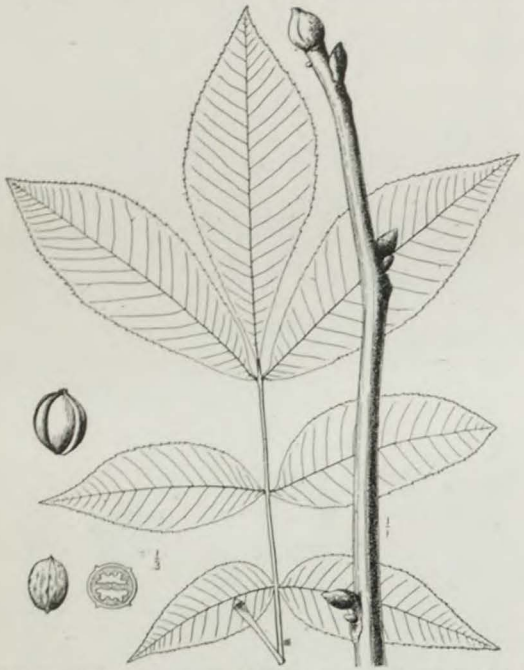

FIG. 3.—Nutmeg hickory (*Hicoria myristicæformis*). Twig, natural size; leaf and fruit, one-third natural size.

The distinguishing characteristics of the pecan are slender branchlets terminated by long slender buds covered with a dark-brown glandular pubescence, resembling those of the walnuts, leaves with 9 to 15 slender leaflets, and elongated, edible nuts about 1 inch in length with thin, ridged husk and thin, brown, bony shells. The bark is dark brown in color, close and finely ridged.

Pecan cultivation is now receiving considerable attention, especially in the Gulf States, and a number of improved varieties are being introduced. Most of the nuts of commerce, however, still come from forest trees in Louisiana and Texas.

WATER HICKORY.

The water hickory (*Hicoria aquatica*), commonly known as the "bitter pecan," bears a strong resemblance to the pecan, especially in the buds, twigs, and leaves. The bark, however, is more scaly and is light gray in color, and the fruit will readily distinguish it from any other hickory. It is usually about an inch long. The husk is thin and splits to the base, and the shell is soft and thin. The nut is flattened, often sharply angled, and the kernel is very bitter.

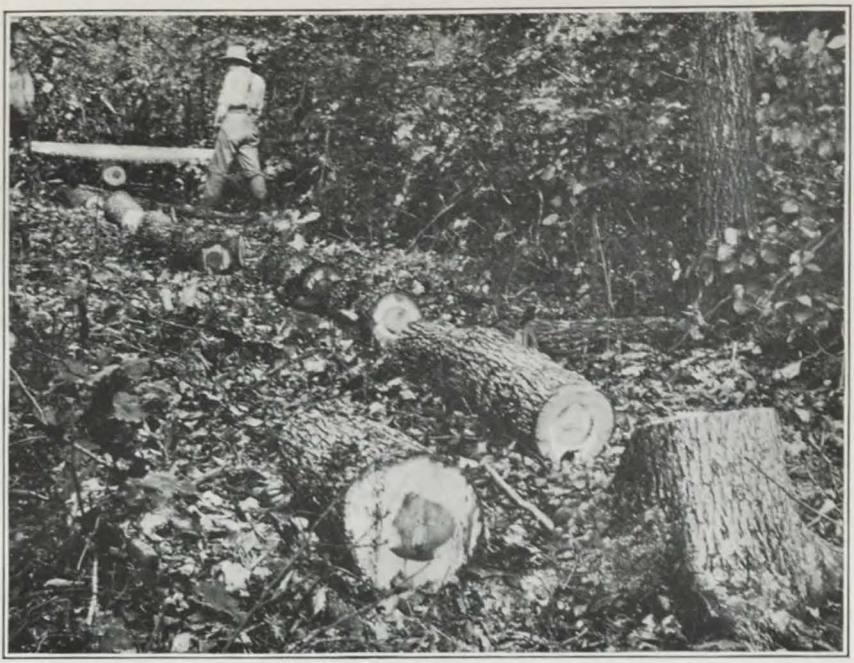

FIG. 1.—SPOKE BOLTS CUT FROM PIGNUT HICKORY.

[This shows a close use of material; the stump is cut low and the tree utilized well into the top. The 28-inch bolts will be hauled to the mill and there cut into billets. Orange County, Ind.]

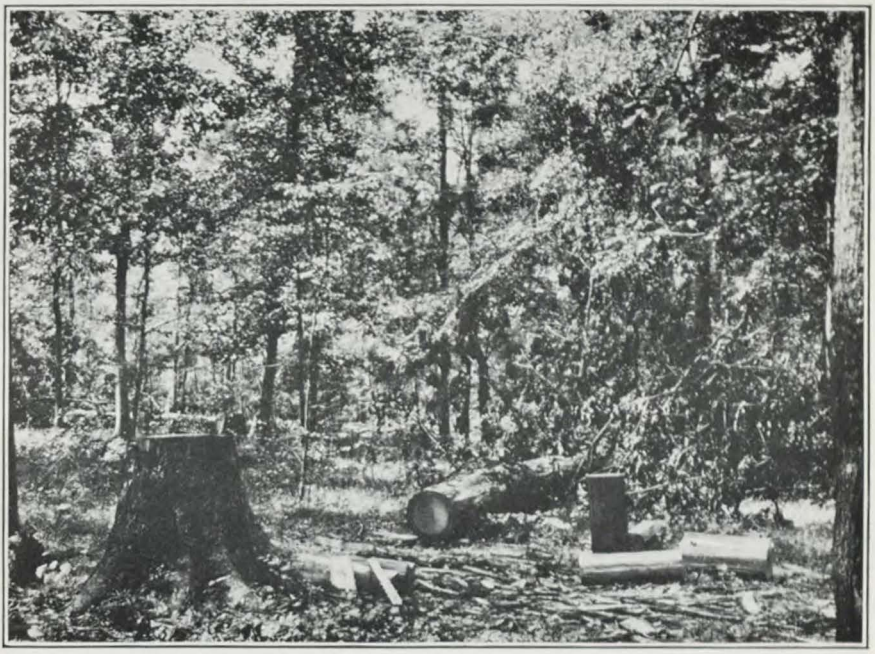

FIG. 2.—WASTE IN HICKORY BOLTS CUT FOR SPOKES.

[This shows the typical waste in the stump and in the material left in the woods. Delhi, La.]

FIG. 1.—TAPROOT OF BITTERNUT, EXPOSED BY THE WASHING AWAY OF THE EARTH ON THE BANK OF A STREAM. DEFIANCE COUNTY, OHIO.

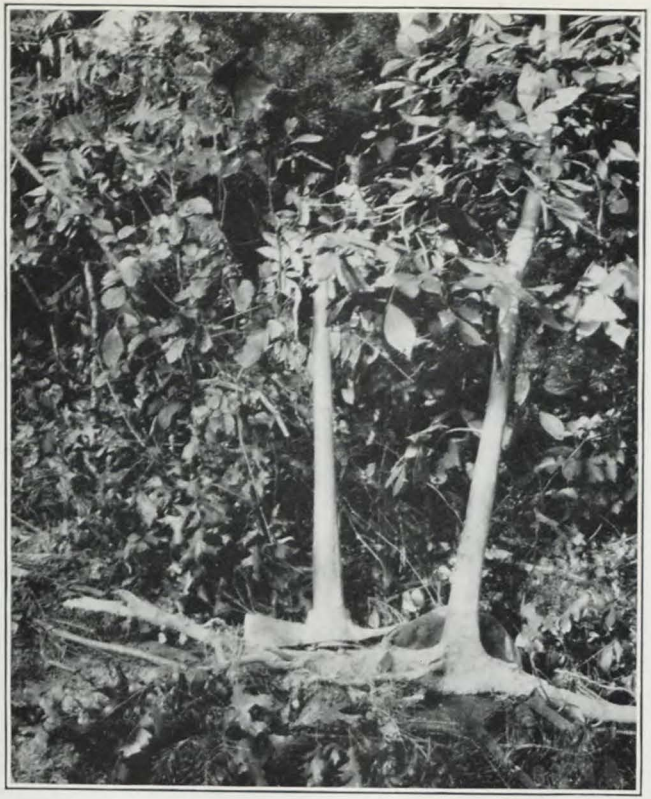

FIG. 2.—ROOT SUCKER OF HICKORY; PARENT ROOT, TO THE RIGHT, GROWS LESS IN THE DIRECTION OF THE PARENT STUMP AND DIES THERE. NO TAPROOT IS FORMED. MADISON COUNTY, KY.

The bitter pecan is generally a small tree and seldom reaches a diameter of more than 2 feet, though it frequently forms a long clear bole.

NUTMEG HICKORY.

The nutmeg hickory (*Hicoria myristicæformis*) is a very distinct species. It is a comparatively small tree, and rarely attains a diameter of more than 2 feet. The bark is thin, brownish gray, and flakes off in short plates. The twigs are slender and gray. The terminal buds are from one-eighth to one-fourth of an inch long, rounded and obtuse, and not long and narrow as in the pecan. The bud scales are covered with a thick brown or yellowish-brown pubescence. The axillary buds are much smaller and narrower than the terminals. The leaves are composed of from 5 to 11 narrow leaflets, which are brownish on the under surface and give to the foliage a characteristic yellowish or brownish cast. The fruit is less than an inch long, usually slightly elongated. The husk has 4 wings that extend from the apex to the base, is only one-eighth of an inch thick, and generally splits to the base. The nut has a bony shell and resembles a nutmeg in size, shape, and color. The kernel is sweet.

FIG. 4.—Bitternut (*Hicoria minima*). Twig, natural size; leaf and fruit, one-half natural size.

BITTERNUT.

Bitternut (*Hicoria minima*) is commonly known through its range as "pignut" or "pig hickory," and in some places as "willow hickory." The term "bitternut" is almost entirely a book name, and is for the most part confined to botanies and to students of botany. This gives rise to much confusion. The tree bears a strong resemblance to the pecan and to the water hickory, especially in the bud characters. The twigs are slender and the buds are long and narrow, and the valvate bud scales are covered with a bright yellow, glandular pubescence, and are the most characteristic feature of the tree. The

leaflets are from 5 to 9 in number, dark green and shiny on the upper side, generally narrow, and sharply toothed. The nut is less than an inch in diameter and is inclosed in a thin, almost papery, husk which splits about two-thirds of the way down and is ridged at the 4 sutures or lines of division. It is smooth and thin shelled, and has a very bitter kernel.

In form the bitternut is tall and slender with a generally straight bole, which prunes itself more readily than most of the hickories. The sapwood is characteristically narrow, seldom over 1½ inches wide or more than 25 years old.

FIG. 5.—Shagbark (*Hicoria ovata*). Twig, natural size; leaf and fruit, one-third natural size.

THE TRUE HICKORIES.

SHAGBARK.

Among the true hickories the common shagbark (*Hicoria ovata*), so called because of its peculiar bark, also known as "scalybark" and "shellbark," is the most widely known.

Of all the hickories, the shagbark is the most distinct in its appearance. As its name suggests, the bark is its most characteristic feature. It is smooth on small trees and grayish in color, but later scales off. On old trees the bark becomes a dark reddish-brown and hangs on in long loose strips or plates. Different trees display all degrees of shagginess. The closer-barked trees are commonly known as "bastard" shagbarks and are preferred by the spoke and handle maker.

The foliage is coarse and heavy, and there are 5 broad leaflets. The twigs are coarse, and both twigs and leaf stalks are usually somewhat hairy. The buds are large, and the terminal buds are often half an inch long; they are acute and covered with dark-brown outer scales. The nuts are the small hickory nuts of commerce and vary considerably in size and thickness of shell. The husk is from one-eighth to three-eighths inch thick, splits to the base, and is somewhat depressed along the sutures.

The shagbark attains large size, and heights of from 130 to 140 feet, and diameters of from 20 to 30 inches are fairly common in the

Cumberland Mountains. In the river bottoms along the Mississippi the trees grow to larger diameters, but the maximum height growth is usually less. One characteristic of the tree is the tendency to fork within the crown into two or three prongs at from one-half to two-thirds the height of the tree.

The southern shagbark (*Hicoria carolinæ septentrionalis*) is a recently distinguished species of little commercial importance. In contrast with the common shagbark, it has a more slender, graceful habit, slenderer and globulous twigs, smaller, more acute buds, with black outer scales, and leaves with from 3 to 5 leaflets. It is fairly common in a limited range from Delaware to northern Georgia, around the base of the Appalachians, and in southern Kentucky. It grows on the lower slopes of the hills, especially on limestone soils, and in the river bottoms.

BIG SHELLBARK.

Very similar in appearance to the common shagbark is the big shellbark, or king nut (*Hicoria laciniosa*), also known as the yellow twig, big-fruited shellbark, and river hickory. Lumbermen rarely differentiate between the two species, although they are quite distinct.

FIG. 6.—Big shellbark (*Hicoria laciniosa*). Twig, natural size; leaf and fruit, one-fourth natural size.

The big shellbark usually has the same scaly bark as the shagbark, though sometimes it is firm and strongly ridged, as in the mockernut of the lower Mississippi Valley. The leaves are rather coarser and heavier, and there are commonly 7 and often 9 leaflets. The most important distinguishing features are the large thick-shelled nuts, often 1½ inches in diameter, strongly ridged and usually much flattened, with husks one-fourth and three-eighths of an inch thick that split all the way to the base and are usually depressed at the sutures, and the stout, buff, or light orange-colored branchlets. These two features distinguish it from any of the other hickories, although occasional hybrids are reported. Another striking feature of the tree is the presence upon the twigs of the previous year's growth of old

leaf stocks, in many cases so numerous as to resemble "witches broom."

In habit the big shellbark is rather shorter and has heavier branches than the shagbark. Generally it is a smaller tree, though in southeastern Missouri it attains a height of from 120 to 130 feet and a diameter of 40 inches breast-high.

PIGNUT.

In botanies and tree manuals the name commonly given to *Hicoria glabra* is "pignut." A tremendous amount of confusion results from this, because in common usage, throughout the whole range of the hickories, the term pignut is applied to an entirely different tree (*Hicoria minima*). The names in common use in the order of their frequency are black hickory, tight bark, switch-top, or simply hickory.

FIG. 7.—Pignut (*Hicoria glabra*). Twigs, natural size; leaf and fruit, one-third natural size.

Of all the hickories none is more important and none offers more difficulties to the botanist. It is exceedingly variable and grows under widely differing conditions of soil and climate. Between four types or variants, which recently have been segregated, there are many intermediate forms.

In the typical *glabra* the bark is generally dark gray in color, and is somewhat flaky or scaly, but never scales off in long plates like the shagbark. In old trees it is strongly ridged, much as that of white ash or elm. The leaflets, leaf stalks, twigs, and buds are entirely free from hairs. The branchlets are slender and the buds small. There are from 5 to 7 leaflets. The fruit is generally pear-shaped and the husk splits less than halfway to the base. The nut is smooth and round, with a thin shell. The kernel is likely to be sweet, but is not easy to get out.

The variety *microcarpa*, which is the common one of the Ohio Valley and which many botanists now describe as a distinct species, has rather coaser twigs than the typical *glabra*. The fruit is smaller and is less frequently pear-shaped; the husk commonly splits freely

to the base and the bark is likely to scale off in flat scales, somewhat like shagbark, though much less pronounced. Some botanists also distinguish another variety, *odorata*, which differs in having larger nuts, and a yellowish glandular pubescence in the buds, leaves, and twigs.

The pale-leaf hickory (*Hicoria villosa*) is a distinct species, but it also may be placed in the pignut group. It is a xerophytic, or drought-resistant, species, and grows mainly in Arkansas and Missouri. It resembles the mockernut in many characteristics and particularly in the bark, which is likely to be deeply fissured and rough, but not shaggy, and has diamond-shaped checks, as in the Mississippi Valley form of the mockernut. The twigs are slender, and twigs, buds, and leaves are covered with a yellowish pubescence. There are from 7 to 9 leaflets, generally small, narrow, thick, dark green, and shiny on the upper side. The fruit varies considerably both in size and shape and often resembles that of the mockernut; but typically it is spherical, with a moderately thin husk, slightly ridged at the sutures, and a thick-shelled, rounded nut, much like that of pignut or mockernut. The tree is rarely more than 60 or 70 feet high. Another species, *pallida*, resembles the *villosa* very closely. It, also, is a xerophytic species, and grows on the hills of Tennessee, Kentucky, and North Carolina. It has the same yellowish pubescence on twigs, buds, and leaves, except that on the leaves the pubescence is rather more woolly. The fruit also is similar, but is somewhat more winged. Frequently the bark is broken into small cubes somewhat like those of the black gum.

FIG. 8.—Small pignut (*Hicoria odorata*). Twig, natural size; leaf and fruit, one-half natural size.

MOCKERNUT.

The mockernut (*Hicoria alba*), known also as the "big bud," "white heart," "white hickory," and "hognut," is most easily recognized by its coarse, hairy leaves and twigs. The leaves have gen-

erally from 7 to 9 leaflets. The fruit varies greatly in size and shape, but commonly is spherical, with a thick husk and a thick-shelled nut, sometimes strongly ridged and sometimes rounded, that contains a small, rather rich kernel. The bark of the tree is never scaly. The characteristic form in the lower Mississippi Valley has deep, diamond-shaped checks or fissures and is light gray in color. Farther east the bark becomes less ridged and the color is more whitish. The sapwood is wide—about 3 inches—and is generally more than 50 years old. The mockernut generally is smaller than either shagbark or pignut. The stem is less likely to be straight, and the branches are heavier.

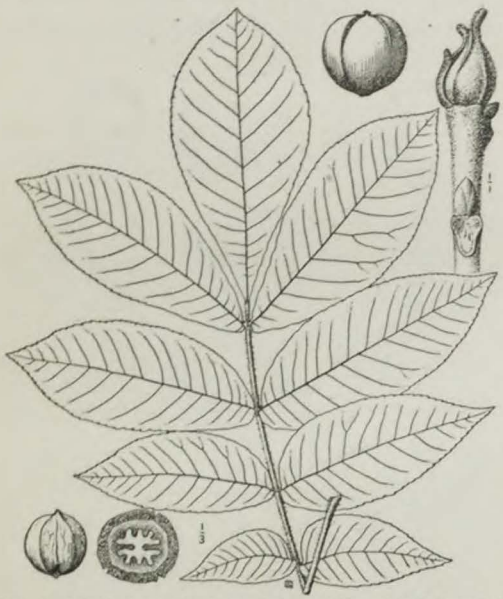

FIG. 9.—Mockernut (*Hicoria alba*). Twig, natural size; leaf and fruit, one-third natural size.

RANGE AND DISTRIBUTION.

In the forest the hickories are rarely predominant. Except through the interference of man, they do not grow in pure stands but always in mixture, somewhat group-wise, with other species, and especially with the oaks. The accompanying maps show the botanical and commercial ranges of the different species of the pecans and of the true hickories.

The botanical ranges show the regions in which the species grow naturally.

The three salient points of the botanical distribution are the comparatively narrow, southern range of the pecan hickories (except the frost-hardy bitternut), confined by the need for warmth and moisture to the river bottoms of the Mississippi Valley and Gulf regions; the wide distribution of the true hickories, especially the pignut and the shagbark; and the centering of the distribution of nearly all the species in the lower Mississippi Valley, in western Tennessee, eastern Arkansas, and northwestern Mississippi.

The commercial distributions show the regions within which the hickory is of sufficient importance to be a factor in forest management. Of all the species, shagbark and pignut are most widely and evenly distributed, and these two furnish the bulk of the hickory of commerce. Shagbark is fairly common in the wood lots of southern

New England and New York, and becomes more prominent westward through southern Pennsylvania and West Virginia. In northern Ohio and Indiana, in the lower Ohio Valley, and in the river bottoms of the lower Mississippi Valley it is the commonest of the hickories. Since most of the remaining virgin hickory is in the lower Mississippi Valley, and since cutting is now especially heavy there, it is probable that most of the hickory on the market is shagbark.

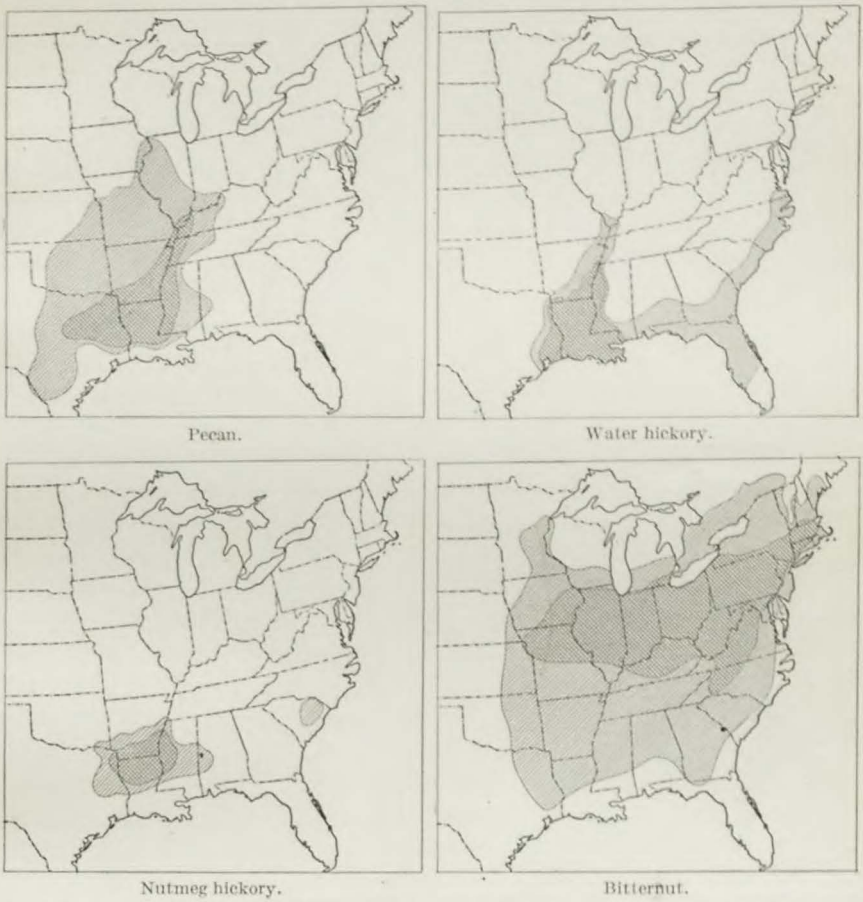

FIG. 10.—Ranges of the pecan hickories. The light-shaded areas show the botanical ranges; the darker areas, the commercial ranges.

The commercial distribution of pignut corresponds closely to that of shagbark, except that it extends farther toward the coast in the southeast. West of the Mississippi it is represented chiefly by the pale-leaf hickory (*villosa*), which, because of its small size, is as yet but little cut. Pignut is most prominent in the Cumberland Mountains of Tennessee, Kentucky, and West Virginia, and on the hills of the Ohio Valley. In these regions it furnishes most of the cut.

Mockernut is characteristically a southern species. It is fairly common in southeastern Pennsylvania and New Jersey, and becomes more

prominent toward the South through Virginia, North Carolina, and Florida, where it is the commonest of the hickories and furnishes the bulk of the cut. It is abundant in the lower Mississippi Valley, but is commercially less important than shagbark.

Big shellbark has a narrow commercial distribution. It is most prominent in the region around the lower Ohio River, south along the Mississippi to central Arkansas, and northeast through the Wabash Valley to northern Indiana and Ohio.

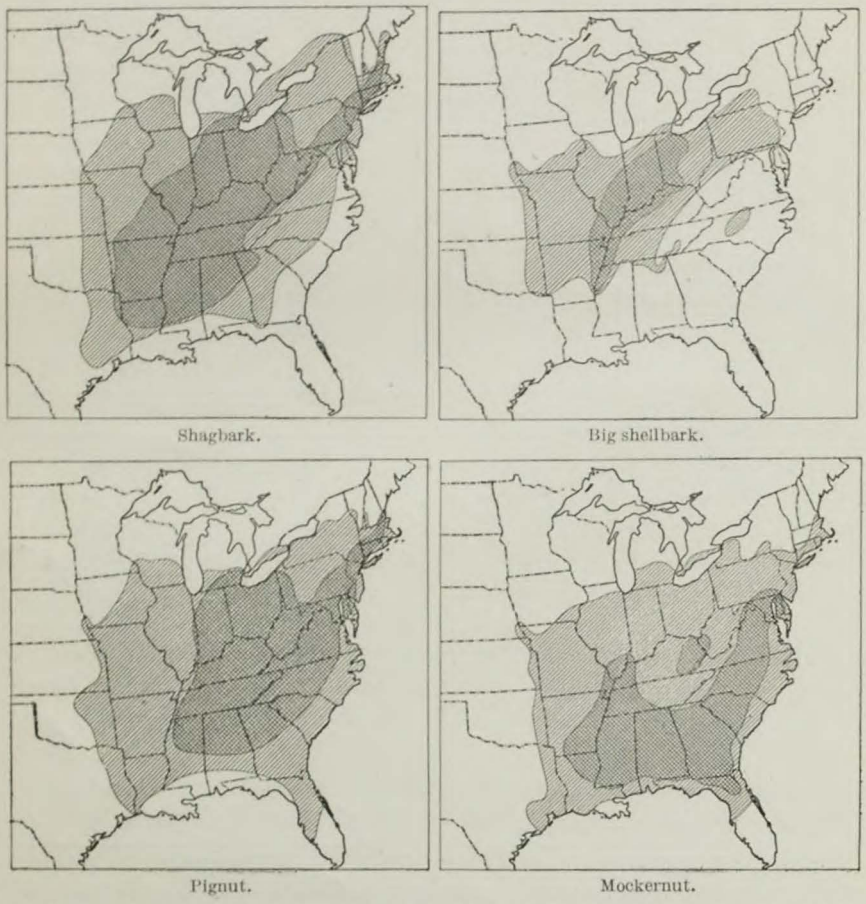

FIG. 11.—Ranges of the true hickories. The light-shaded areas show the botanical ranges; the darker areas, the commercial ranges.

The pecan hickories can not be said to be of commercial importance, because they are seldom cut. Bitternut is fairly common from southern New England west to Iowa and from southern Michigan south to Kentucky. South of Kentucky it is somewhat rare. Pecan grows as far north as Dubuque, Iowa, but is rare and local north of the Ohio River. Along the Mississippi, southward from the mouth of the Ohio, it grows gradually more common, until, in southern Arkansas and in Louisiana, it becomes an important factor in the forest. It is also

common in eastern Texas. The water hickory is common only along the lower Mississippi and in eastern Texas, and nutmeg hickory, the rarest of them all, grows mainly in southeastern Arkansas.

SOIL AND MOISTURE REQUIREMENTS.

In general, the hickories are exacting in their soil requirements, though in this respect there is a wide variation within the genus. Stunted mockernuts grow in Alabama and Mississippi upon the sandy shortleaf and loblolly pine land; the drought-enduring pale-leaf hickory grows on the dry hillsides of western Arkansas and Missouri; pignut and mockernut grow in dry situations, such as west and south slopes, or dry ridges in the Cumberlands, or the knobs of southern Indiana. In all these drier situations, however, the trees are likely to be stunted, defective, and usually badly bird pecked; even the drought-enduring species requires for good development soils that are moderately fresh and fertile. Most of the merchantable mockernut and pignut grows on fairly fertile uplands with white oak, black oak, scarlet oak, and post oak, and the very best development is attained only on fresh, deep, fertile soil. Pignut in particular responds readily to the increased fertility of the soil, and in the coves of the Cumberland Mountains, associated with white oak, red oak, yellow poplar, basswood, buckeye, white ash, beech, maple, and shagbark, it is the largest of the hickories. On the river bottoms of the Mississippi it attains larger dimensions than any other hickory, except the pecan.

At the other extreme, water hickory grows with cypress where the ground is wet all the year round and water stands during most of the year. Pecan and nutmeg hickory are only a little less moisture loving. They grow usually on the overflow lands of the South, associated with sweet gum, tupelo, white oak, cow oak, overcup oak, white and blue ash, and but rarely grow in drier situations except when planted there. Big shellbark and bitternut also are moisture-loving species. The former grows usually in river bottoms or on the banks of streams throughout its range, associated with elm, white ash, white oak, cow oak, overcup oak, and shagbark hickory; the latter, which has a more northern distribution, grows along streams, on rich bottom lands, and on north and east slopes associated with elm, white, red, and pin oak, white ash, shagbark and big shellbark hickory. The widely distributed shagbark shows to a marked degree the tendency to seek moister situations in its southern range and drier ones to the north. In the Ohio Valley it grows chiefly on fertile uplands on north and east slopes; in the Cumberlands it is confined to the coves and to north and east slopes. At lower elevations southward it seeks moister situations, and in Arkansas, Mississippi, and Louisiana grows only in the river bottoms. Throughout its range shagbark is commonly associated with white oak and white ash,

and in the Cumberland Mountains grows also with red oak, yellow poplar, basswood, buckeye, beech, and sugar maple.

In their soil and moisture requirements, beginning with those which require least moisture, the hickories rank as follows: Pignut, mockernut, shagbark, bitternut, big shellbark, nutmeg hickory, pecan, water hickory.

TOLERANCE.

Most hickories require but little light in early life, and grow under fairly dense shade. A peculiar feature of the tolerance of hickories is the remarkable rapidity with which they recover from suppression. After being suppressed for from sixty to eighty, or even one hundred years, during which time they reach diameters of only a few inches, they are able to respond to the stimulus of increased light and immediately begin to expand their crowns and put on heavy layers of wood. A tree which has been suppressed and is then freed by an opening in the forest cover will often develop at a faster rate of growth than that of a normal tree of the same size and diameter which has never been suppressed. This capacity for enduring shade is so strong in pignut and shagbark that the largest diameter increase may come at the age of 150 or even 200 years.

In short, big shellbark and pignut are only slightly less tolerant than sugar maple and beech of those trees which grow in the central hardwood belt. This tolerance is common to the whole genus, though different species show varying degrees of tolerance; the true hickories are all more tolerant than the pecans. In the order of tolerance from those which require least to those which require most light, they rank as follows: Pignut, shagbark, big shellbark, mockernut, bitternut, nutmeg hickory, pecan, water hickory.

The great shade-enduring capacity of most of the hickories is of the utmost importance to reproduction, for to this capacity is due the ability of the tree to hold its own in the forest.

REPRODUCTION.

Hickory is reproduced both by seed and by sprout. Seedling reproduction, even in the virgin forest and under dense shade, is made possible by the great tolerance of the young trees. The nuts are borne at irregular intervals, but good seed years come practically every other year. Nuts are seldom borne by trees under 5 inches in diameter. Thrifty hickories standing in the open will frequently bear as many as 2 or even 3 bushels of shelled nuts in a year, and improved varieties of pecans will bear 15 bushels. Only a small proportion of the seed is left to germinate, however, because squirrels, mice, hogs, and man eat great quantities of the nuts, especially of the sweet-kerneled pecans and shagbarks. Squirrels especially are to be reckoned with, not altogether as enemies, but as friends; although

they live upon the nuts, they also bury them in the ground, and it is largely through the agency of squirrels that the nuts are carried out from under the shade of the parent tree, and the hickories thus get a foothold in territory where seed trees are lacking.

During the first few years the seedling spends most of its energy in developing a taproot. Measurements of 32 seedlings growing in heavy red clay soil showed that at one year the average shagbark had a root about 12 inches long, the bitternut 11 inches, and the big shellbark 13 inches. At 3 years of age the root of the big shellbark is about 2½ feet long and the roots of the other hickories are about the same length.

The height growth of seedlings in the Ohio Valley in the open or under light shade, on red clay soil, is shown in Table 1.

TABLE 1.—*Height growth of seedlings.*

	Age—years.						
	1.	2.	3.	4.	5.	6.	7.
	Height—inches.						
Shagbark	2.8	4.2	7.8	12.0	17.0	.....	.....
Pignut	3.0	5.8	8.0	12.0	17.0	.....	.....
Mockernut	3.0	4.7	8.0	12.5	20.0	28.0	.....
Bitternut	3.5	6.3	9.5	13.3	19.5	27.0	.....
Big shellbark	4.3	6.0	11.0	16.0	22.0	.....	.....
Pecan	6.4	12.0	19.0	28.0	.....	.....	.....

This table is not based on a sufficient number of seedlings to be entirely conclusive, but it shows the relatively rapid growth of pecan and big shellbark and the slow growth of shagbark, pignut, and mockernut.

Seedlings of large size are rare because seedlings usually meet with an accident which kills them back and puts them in the class of "seedling sprouts." Fire and pasturing are the chief sources of such accidents, which, however, are not unmixed evils, because young hickory sprouts readily, and the stool quickly sends out rapid-growing shoots that are generally straighter than the original seedling. Hickory is a very persistent sprouter when young. The sprouts will stand heavy shade and will come up, time after time, undiscouraged by repeated burnings and cutting back. In this property hickory excels all other hardwoods of the central hardwood region. Partly through this and partly through the fact that hickory is one of the last trees which cattle will eat, large areas of pasture land, especially in Ohio and Indiana, are occupied by pure stands of hickory sprouts. Occasionally, also, abandoned fields are so occupied. In both cases such stands are usually too open, and the trees are scrubby and knotty.

Throughout the Ohio Valley and the central hardwood region generally, there is excellent reproduction of hickory in thickets under the

older stands, and most of the saplings are seedling sprouts. In the river bottoms of the South, however, the reproduction generally is poor; this may be due to the fact that the ground is covered with water during the winter and the nuts are washed away, or to the fact that the stumps seem to sprout less readily in this region, or to the large number of hogs to eat the nuts.

Most of the hickories now standing are either seedlings or sprouts from small stumps. Coppice hickory is not nearly as common as coppice chestnut or oak, because hickories are slow-growing and their sprouting capacity diminishes rapidly with age; trees which have reached merchantable size can not be depended on to produce sprouts. Furthermore, hickory sprouts grow more slowly than those of other broad-leaf trees, and can not compete with them in even-aged stands.

Sprouts may grow from the stump, the root collar, and the root. Stump sprouts are exceptional; and the tendency toward root sprouts, or suckers, increases with the size and age of the tree. Table 2, based on measurements of 183 stumps of shagbark hickory, shows that as the stumps increase in size, the number that produce sprouts decreases, and that the proportion of root suckers increases.

TABLE 2.—*Vigor and method of sprouting with increase in diameter of stump in shagbark hickory.*

Diameter of stump.	Stumps producing sprouts.	Sprouts from stump.	Sprouts from collar.	Sprouts from root.	Height of sprouts 1 year old.
Inches:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Feet.*
2	100	12.0	88	0.0	3.15
3	100	11.0	85	6.0	3.10
4	100	10.0	76	14.0	3.05
5	100	9.0	70	21.0	3.00
6	100	8.0	64	28.0	2.95
7	100	7.5	58	34.5	2.90
8	100	7.0	52	41.0	2.80
9	92	6.0	45	49.0	2.75
10	85	5.0	40	55.0	2.70
11	75	4.5	35	61.0	2.65
12	66	4.0	30	66.0	2.60
13	56	3.5	25	71.5	2.55
14	47	3.0	22	75.0	2.50
15	37	2.5	19	78.5	2.40
16	26	2.0	17	81.0	2.30
17	17	1.5	17	82.5	2.15

Of northern species bitternut is the best sprouter, and the average height of dominant 1-year-old sprouts from 20 stumps was 4.7 feet. One-year-old sprouts from 31 stumps of pignut showed an average height of 3.3 feet as against an average of 2½ feet for the 183 stumps, of shagbark, though there is but little difference in the sprouting capacity of the two species.

The distance of the root suckers from the stump increases with the size of the stump. The maximum distance is about 8 feet and the average about 2 feet. As a rule, the sucker does not produce a taproot but merely appropriates the parent root.

GROWTH.

The hickories are comparatively slow-growing, especially the true hickories. Pecan grows rather rapidly, is long-lived, and is persistent in its growth; the bitternut grows rapidly at the start, though it rarely reaches large size. The true hickories, however, are even slower-growing than white oak. A 200-year-old white oak growing under the same conditions of light and soil as a shagbark or pignut of the same age often will have almost twice the diameter and will yield from two to four times as much merchantable material. No growth figures were secured for pecan, water, or nutmeg hickory, since they are unimportant commercially, and no cuttings were found. Figures for the other species were taken for typical situations in five different regions.

As previously shown, the hickories are generally suppressed in early life. Therefore, to secure figures that would be applicable to trees grown under forest management, the periods of suppression have been disregarded in the preparation of Table 3, which gives the time required for a normal tree to increase 1 inch in diameter.

TABLE 3.—*Time required by trees of various diameters to make 1 inch of diameter growth.*

Diameter breast-high.	Eastern Maryland and Pennsylvania.		Ohio Valley.			Northern Ohio.		Cumberland Mountains.			Mississippi Valley.			
	Pignut.	Mockernut.	Pignut.	Shagbark.	Bitternut.	Pignut.	Shagbark.	Pignut.	Shagbark.	Mockernut.	Pignut.	Shagbark.	Mockernut.	Shellbark.
Inches:	*Yrs.*	*Yrs.*	*Yrs.*	*Yrs.*	*Yrs.*	*Yrs.*	*Yrs.*	*Yrs.*	*Yrs.*	*Yrs.*	*Yrs.*	*Yrs.*	*Yrs.*	*Yrs.*
1	11	10	9	9	9	11	9	11	9	8	11	8	7	13
2	11	8	8	9	8	10	9	11	8	8	10	8	7	11
3	10	8	8	8	8	9	9	10	8	8	9	8	7	11
4	9	7	8	8	7	8	9	10	8	8	8	8	7	11
5	8	7	7	8	7	8	9	9	8	8	8	8	7	10
6	8	6	7	8	6	8	8	9	8	8	8	8	7	10
7	8	6	7	8	6	8	8	8	8	8	8	8	7	10
8	7	6	7	8	6	8	8	8	8	8	8	8	7	9
9	7	6	7	8	6	8	9	8	8	8	8	8	7	9
10	7	6	7	8	7	8	9	8	8	8	8	8	7	9
11	7	6	7	8	7	8	9	8	8	8	8	8	7	8
12	6	6	7	8	7	8	9	8	8	8	8	8	7	8
13	6	6	7	8	8	8	10	8	8	8	8	8	7	8
14	6	7	8	8	8	8	10	8	8	8	8	8	7	8
15	6	7	8	8	9	8	11	8	8	8	8	8	7	8
16	6	7	8	8	10	9	.....	8	8	8	8	8	7	8
17	6	7	8	8	.....	9	.....	8	8	8	8	8	7	8
18	6	8	8	8	.....	10	.....	8	8	8	8	8	7	8
19	6	8	.....	.....	.....	10	.....	8	8	8	8	8	7	8
20	6	8	.....	.....	.....	11	.....	8	8	9	8	8	8	8
21	6	8	.....	.....	.....	11	.....	8	8	9	8	8	8	8
22	6	8	.....	.....	.....	13	.....	8	8	10	8	8	8	8
23	6	9	.....	.....	.....	.....	.....	8	8	10	8	8	8	8
24	6	9	.....	.....	.....	.....	.....	8	8	11	8	8	8	9
25	7	10	.....	.....	.....	.....	.....	8	9	.....	8	8	8	9
26	7	.....	.....	.....	.....	.....	.....	8	9	.....	8	7	8	10
27	7	.....	.....	.....	.....	.....	.....	8	9	.....	8	7	8	.....
28	7	.....	.....	.....	.....	.....	.....	9	9	.....	8	7	8	.....

The rapid growth shown in eastern Maryland and Pennsylvania is due to extremely favorable conditions. The trees measured were growing on agricultural soils of excellent quality, deep reddish sandy loams underlain by gneiss, and the stands had been opened up and growth stimulated. The trees measured in the Mississippi Valley and Cumberland Mountains also were growing on good soils, the former on rich alluvial soils of river bottoms, and the latter generally on rich north and east slopes. Their slow growth is due to their development in the virgin forest, though their extreme persistency indicates that under management their growth in either region would be as fast as if not faster than in eastern Maryland. In the Ohio Valley the trees were growing on low hills which characterize southern Indiana and northern Kentucky, on less favorable soils, mainly red clay, with the underlying rock, sandstone, limestone, or slate. The trees, however, were strictly second growth. In northern Ohio the land is flat and is underlain by a stiff, almost impermeable clay, which keeps the top soil wet most of the year. The trees measured were strictly second growth.

Pignut, shagbark, and big shellbark hickories show similar rates of growth, and all three are very persistent. Mockernut and bitternut grow more rapidly at first, but the rate soon decreases and the trees seldom reach large size.

Table 4, made up from measurements of second-growth trees in southern Indiana and northern Kentucky, shows approximately what may be expected from hickory grown under forest management.

TABLE 4.—*Diameter growth of normal second-growth hickory.*

Age.	Diameter breast-high of—		
	Pignut.	Shagbark.	Bitternut.
Years:	*Inches.*	*Inches.*	*Inches.*
10	1.0	1.2	2.0
20	2.0	2.8	4.0
30	3.2	4.0	6.0
40	4.4	5.4	7.6
50	5.5	6.8	9.2
60	6.8	8.0	11.4
70	8.4	9.4	13.0
80	10.0	10.5	.....
90	11.4	11.6	.....

The pignut was growing on only moderately good soil, the shagbark on soil of somewhat better quality, and the bitternut on very good soil. Under similar soil and light conditions there would probably be little, if any, difference between pignut and shagbark. Bitternut, however, is not only a faster-growing tree, but grows characteristically on the richer soils.

Table 5 gives figures of height growth of a few carefully selected trees growing under soil conditions similar to those of the trees given in Table 4.

TABLE 5.—*Height growth of various hickories.*

Age—years.	Ohio Valley.			Northern Ohio.	Cumberland Mountains.			Mississippi Valley.		
	Shagbark.	Pignut.	Bitternut.	Pignut.	Shagbark.	Pignut.	Mockernut.	Shagbark.	Pignut.	Mockernut.
	Height—feet.									
10	7	9	10	7	3	6	4	4	6	9
20	18	19	24	20	13	14	17	8	19	18
30	32	32	40	35	20	24	26	15	27	25
40	43	42	52	48	27	32	33	23	34	30
50	51	51	62	61	34	40	39	32	40	35
60	58	58	69	69	41	48	45	41	46	40
70	64	64	.....	74	48	55	50	50	52	44
80	70	69	.....	.....	54	62	55	58	58	49
90	75	.....	.....	.....	60	69	60	65	64	53
100	79	.....	.....	.....	66	75	66	71	69	57
120	.....	.....	.....	.....	78	85	76	81	79	65
140	.....	.....	.....	.....	89	93	85	90	88	73
160	.....	.....	.....	.....	99	99	94	97	96	80
180	.....	.....	.....	.....	108	104	102	103	101	88
200	.....	.....	.....	.....	116	108	109	109	105	95

This explains why the trees in the Cumberland Mountains and in the Mississippi Valley, in spite of better soil conditions, show a slower growth. The figures given for the Cumberland Mountains and the Mississippi Valley are from trees in the virgin forest; those for the Ohio Valley and for northern Ohio are from second-growth trees. Under forest management the growth of trees in these regions should be faster than in the Ohio Valley and in northern Ohio.

Coppice hickory of merchantable size is scarce. Table 6 is based on measurements of 16 pignuts and 6 shagbarks growing in rather dry situations, on red clay soil, both near Bardstown, Ky., and Paoli, Ind. Under more favorable conditions the growth should be considerably faster.

TABLE 6.—*Height and diameter growth of pignut and shagbark coppice.*

Age.	Pignut.		Shagbark.	
	Diameter.	Height.	Diameter.	Height.
Years:	*Inches.*	*Feet.*	*Inches.*	*Feet.*
10	2.0	18	2.4	13
20	3.8	31	4.4	26
30	5.5	43	6.3	38
40	7.0	52	7.4	46
50	8.5	59	8.6	54

LENGTH OF LIFE.

The hickories are long-lived trees, though not as long-lived as oaks. Pecan probably reaches the greatest age. A tree on the St. Francis River in Arkansas was 382 years old, 146 feet high, and 48 inches in diameter. The section of big shellbark in the Morris K. Jesup collection in the American Museum of Natural History in New York shows 340 annual rings. The oldest shagbark and the oldest pignut found grew in West Virginia and were each 350 years old. Mockernut is apparently shorter lived. Several trees, however, in the Mississippi Valley were over 260 years old. Water hickory, nutmeg hickory, and particularly bitternut, are even shorter lived than the mockernut. Mature trees of shagbark and pignut are usually from 200 to 300 years old and grow in the virgin forest along with white oak and other long-lived species.

SUSCEPTIBILITY TO INJURIES.

Though comparatively free from serious dangers and diseases, hickory, in common with all other trees, is subject to various injuries.

A serious injury from the commercial standpoint, though of little danger to the life of the tree, is what is known as "birdpeck." This is a discoloration of the wood caused chiefly by the work of the sapsucker, which, especially in the spring, drills into the cambium of the tree after the sap. The hole cuts off the flow of sap, and a black streak from one-eighth to three-eighths inch wide extends a foot or so above and below the wound along the line of the pores affected. This streak probably does not affect seriously the strength or toughness of the wood, but it does affect the appearance, and the prejudice against "streaky hickory" is very strong.

Birdpecks are most prevalent in trees on south slopes and in situations where the sap will flow most quickly on warm winter days or in the early spring. The damage is very extensive, and an immense amount of wood—perhaps as much as 10 per cent of the merchantable material—is left in the woods on account of birdpeck.

The living hickory trees support a large number of different kinds of insects, some feeding on the leaves, others on the nuts, and still others on the bark and wood of the twigs, branches, and trunks, but there is only one species responsible for any extensive dying of the trees. This is the hickory barkbeetle (*Scolytus quadrispinosus*) which, during the past ten years, has been directly responsible for the death of so much of the best hickory timber throughout the area in which the hickory grows, but especially in the northern section of its distribution, from Connecticut to Wisconsin. Wood of the living trees, especially of the younger ones, is injured to some extent by wood-boring grubs or larvæ of several species of long-horned beetles of the genus *Goes*. The wood of dying and dead trees, and of sawlogs, handles, poles, and other unseasoned products with the bark on,

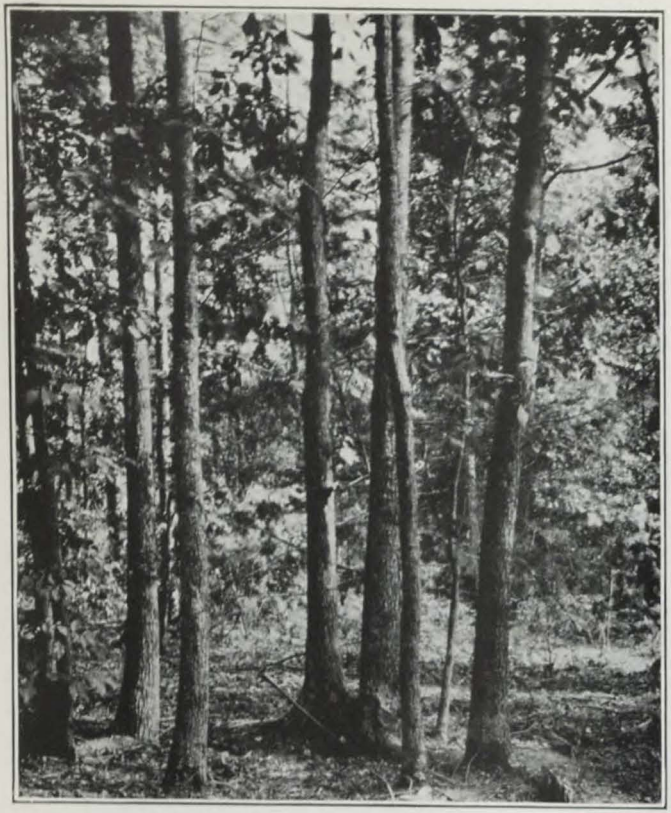

FIG. 1.—A GROUP OF STUMP SPROUTS OF PIGNUT. NELSON COUNTY, KY.

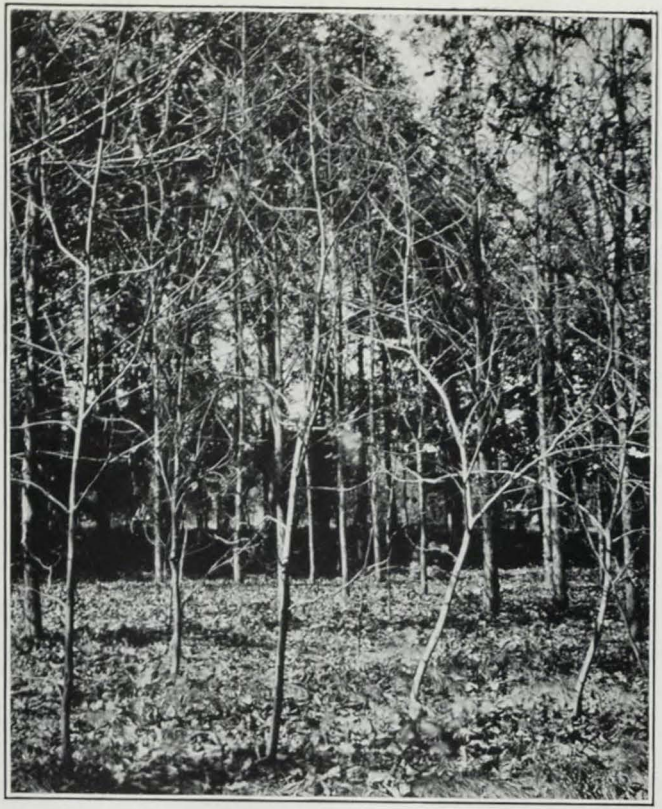

FIG. 2.—HICKORY SPROUTS COMING UP FROM THE ROOTS.

is often seriously damaged by various kinds of wood-boring beetles and larvæ. The sapwood of all kinds of hickory wood products, even after seasoning, is subject to great damage by various species of powder post insects. In short, insect injury has contributed greatly to waste in hickory, and has reduced revenues and profits. Practical methods of preventing losses from these insects have been determined and may be adopted and successfully carried out at slight expense.[a]

A very serious defect of hickory trees is "cup-shake." This occurs commonly in the heartwood of mature trees in those portions where the growth has been very slow, and consequently a number of open porous layers come together. It is most common where the porosity of the wood is increased by a large amount of moisture in the soil, and therefore most likely to occur in southern hickory. There are two ways by which loss from this source can be entirely avoided, first, by keeping the trees growing steadily, so that no succession of narrow rings will be formed, and, second, by cutting them before they reach large size.

Young hickories are very susceptible to frost. Out in the open, without protection from an older stand, they are apt to be killed back by frost, and this forms one of the chief objections to growing hickory in plantations in the northern part of its range; it has proved an obstacle to the introduction of the hickories into Germany, where big shellbark and mockernut are too sensitive to grow successfully. Bitternut, pignut, and shagbark are unquestionably the least susceptible to frost and pecan and water hickory the most.

A source of considerable injury in some places is the practice of bumping or striking against the trunks of young shagbarks or big shellbarks with a heavy object or a long pole to shake down the nuts in the fall. It causes serious defects, if not actual decay in the wood.

VOLUME AND YIELD.

VOLUME.

One of the first things which a practical lumberman wants to know about a tree is how much merchantable lumber it contains and what is its quality; he usually answers this by estimating the product which may be obtained from it. By long years of experience he becomes very skillful in thus determining the contents of a tree. In buying and selling stumpage it is essential to determine the volume of single trees, for by the estimates of individual trees the value of the stand is determined.

To determine the value of a particular tree, the most satisfactory method is to estimate the number and size of the logs which it con-

[a] For specific information about the insects injurious to hickory or other forest trees, inquiries should be made directly to the Bureau of Entomology, U. S. Department of Agriculture, and, whenever possible, specimens of the insects and of their work should be submitted.

tains. This is particularly true in the case of hickory, in which freedom from knots and birdpecks, rapidity of growth, and width of sapwood are so important, and vary so greatly under different conditions. In an open stand, for instance, the trees run knottier and there is less merchantable length, but the growth is more rapid and the quality of the wood is better. In poor or exposed situations the growth is slow and the wood is apt to be birdpecked. Lumbering, moreover, differs greatly with the region and the purpose of cutting. A great deal more of the tree is used, for instance, when it is cut for handles than when it is cut for rims or shafts, and utilization is much closer in the North and East than it is in the Mississippi Valley.

Nevertheless, it is important, also, to know how much wood average trees of different sizes contain and how much is merchantable. The average tree can be used in estimating, and, when applied to a large number of trees, gives fairly satisfactory results. It is especially valuable in predicting future yields and can be used to foretell the increase in volume of a 10 or 12 inch tree after it has made a certain definite increase in diameter.

While the merchantable volume of two hickory trees of the same diameter and height may differ greatly, there is apt to be a greater difference between a hickory and an oak or an ash of similar dimensions. Each species has its own characteristic form and its own special uses. It is therefore desirable to determine the contents of the average trees of each species. For this purpose a large number of trees of different sizes were measured and, in the case of this hickory study, not only were their merchantable volumes determined, but the amount of firewood contained in the tops. The amount of heart, sap, and bark in the used portions and the form of the entire stem were also measured.

Table 7 shows the total cubic contents including bark and limbs for trees from 40 to 90 feet high and 5 to 18 inches in diameter, breast-high. The average used volume is given in per cent of the total volume. The table is based upon the measurements of 365 trees of five different species of hickory cut in different parts of the country for spokes, handles, rims, and shafts. In the merchantable portions, the diameters were taken to tenths of inches; in firewood, only 4-foot sections, 2 inches and over at the small end, were considered, and the diameters were measured in the middle of the sticks and rounded off to half inches. The volumes are given in cubic feet, since this is the most accurate unit of measure for timber of different classes. To convert cubic feet into board feet it may be considered that 1 cubic foot of merchantable material will saw from 5 to 7 board feet, or, on an average, 6 board feet. To convert cubic feet into cords, it may be assumed that 95 cubic feet of spoke or handle bolts is equal to 1 stacked cord; and that 1 cord of firewood would contain from 60 to 90 cubic feet, depending on the size and straightness of the sticks;

with an average of 80 cubic feet. This table is of value in estimating future yields and in estimating firewood in the thickly settled regions of the North where hickory is closely utilized. It may be used for estimating, though with caution, since it represents so many different regions and conditions that it is not strictly applicable to specific cases.

TABLE 7.—*Total cubic contents of hickories and proportion of used volume.*

Diameter breast-high—inches.	Height—feet.						Used volume—per cent.
	40.	50.	60.	70.	80.	90.	
	Total volume—cubic feet.						
5	2.1	3.1	4.3	6.0	.....	.....	40
6	3.3	4.5	5.9	7.8	.....	.....	41
7	4.7	6.2	7.9	9.9	12.6	.....	42
8	6.4	8.2	10.1	12.5	15.5	18.7	44
9	8.2	10.4	12.8	15.5	18.8	22.5	45
10	10.4	13.0	15.8	19.0	22.6	26.7	47
11	12.8	15.9	19.3	23.0	27.0	31.5	49
12	15.6	19.0	23.2	27.4	31.9	36.8	50
13	.....	22.6	27.5	32.1	37.2	42.8	52
14	.....	.....	32.0	37.2	43.0	49.2	53
15	.....	.....	36.8	42.6	49.1	55.8	53
16	.....	.....	.....	48.4	55.5	62.8	54
17	.....	.....	.....	54.5	62.5	70.4	54
18	.....	.....	.....	60.8	69.8	78.8	54

Table 8 gives cubic contents according to diameter and merchantable length. It is based upon the measurements of 630 trees. By its use the total contents of a tree may be estimated without reference to the individual logs.

TABLE 8.—*Cubic contents of hickory according to diameter and merchantable length.*

Diameter breast-high—inches.	Merchantable length—feet.													Diameter inside bark of top—inches.
	5.	10.	15.	20.	25.	30.	35.	40.	45.	50.	55.	60.	65.	
	Volume—cubic feet.													
5	1.0	1.8	2.3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4
6	1.3	2.5	3.2	3.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	5
7	1.6	3.2	4.2	5.0	5.7	.....	.....	.....	.....	.....	.....	.....	.....	6
8	2.0	4.0	5.4	6.5	7.5	.....	.....	.....	.....	.....	.....	.....	.....	6
9	2.5	4.8	6.6	8.2	9.6	10.0	.....	.....	.....	.....	.....	.....	.....	7
10	3.0	5.8	8.1	10.0	11.5	13.0	.....	.....	.....	.....	.....	.....	.....	8
11	3.5	6.9	9.7	12.0	14.0	16.0	18.0	.....	.....	.....	.....	.....	.....	8
12	4.1	8.0	11.5	14.5	17.0	20.0	21.5	23.5	.....	.....	.....	.....	.....	9
13	4.8	9.3	13.5	17.0	20.5	23.5	26.0	28.5	31	.....	.....	.....	.....	10
14	5.5	10.5	15.5	20.0	24.0	27.5	31.0	34.0	37	.....	.....	.....	.....	11
15	6.2	12.0	17.5	23.0	27.5	32.0	36.0	39.0	43	.....	.....	.....	.....	11
16	7.0	14.0	20.0	26.5	31.0	36.0	41.0	45.0	50	54	.....	.....	.....	12
17	8.0	15.5	23.0	29.5	36.0	41.0	46.0	51.0	56	61	66	.....	.....	13
18	.....	17.5	25.5	33.0	40.0	46.0	52.0	58.0	63	69	74	.....	.....	14
19	.....	19.5	28.5	37.0	45.0	52.0	58.0	64.0	70	76	82	.....	.....	14
20	.....	21.5	32.0	41.0	50.0	57.0	64.0	71.0	78	84	90	97	103	15
21	.....	24.0	35.0	45.0	54.0	63.0	71.0	79.0	86	93	100	107	113	16
22	.....	26.0	38.0	50.0	60.0	69.0	77.0	86.0	94	102	110	118	126	16
23	.....	28.5	42.0	54.0	65.0	75.0	84.0	93.0	102	111	120	128	137	17
24	.....	31.0	45.0	59.0	70.0	81.0	91.0	102.0	111	121	130	139	148	18
25	.....	34.0	49.0	64.0	76.0	88.0	99.0	110.0	121	130	140	149	158	19
26	.....	36.5	53.0	69.0	82.0	95.0	107.0	119.0	130	140	151	161	171	19
27	.....	.....	57.0	74.0	89.0	103.0	116.0	128.0	140	151	162	173	183	20
28	.....	.....	61.0	80.0	97.0	112.0	125.0	137.0	149	161	173	185	197	20

Table 9, based on 630 trees, shows, according to diameters, the general average total height and merchantable length. In cases where diameters alone are known, the table may be used with caution to supply the missing merchantable lengths.

TABLE 9.—*Relation between height and merchantable length of hickories of various diameters.*

Diameter breast-high.	Height.	Average merchantable length.	Diameter breast-high.	Height.	Average merchantable length.
Inches:	*Feet.*	*Feet.*	Inches:	*Feet.*	*Feet.*
5	37	6	21	112	32
6	43	8	22	115	33
7	50	10	23	117	35
8	56	12	24	119	36
9	61	14	25	121	37
10	67	16	26	122	39
11	72	17	27	124	40
12	77	19	28	125	42
13	82	20	29	126	43
14	86	22	30	127	44
15	91	23	31	128	46
16	95	25	32	129	47
17	99	26	33	130	49
18	102	28	34	131	50
19	106	29	35	132	51
20	109	30	36	132	52

Table 10, based on 600 trees, shows the proportion of heartwood, sapwood, and bark in the merchantable portions of trees of different diameters. It may be used in connection with Table 8 to show how much must be allowed for bark and what proportion of the cut is sapwood.

TABLE 10.—*Proportion of heartwood, sapwood, and bark in hickories of different diameters.*

Diameter breast-high.	Heartwood.	Sapwood.	Bark.	Diameter breast-high.	Heartwood.	Sapwood.	Bark.
Inches:	*Per cent.*	*Per cent.*	*Per cent.*	Inches:	*Per cent.*	*Per cent.*	*Per cent.*
5	3	75	22	21	42	43	15
6	6	73	21	22	43	42	15
7	9	71	20	23	45	40	15
8	13	68	19	24	47	39	14
9	15	66	19	25	48	38	14
10	18	64	18	26	49	37	14
11	20	62	18	27	50	36	14
12	23	60	17	28	50	36	14
13	25	58	17	29	51	35	14
14	28	56	16	30	52	35	13
15	30	54	16	31	52	35	13
16	32	52	16	32	53	34	13
17	34	50	16	33	53	34	13
18	37	48	15	34	54	33	13
19	39	46	15	35	54	33	13
20	40	45	15	36	55	33	12

Table 11 shows the proportion of heartwood, sapwood, and bark in the merchantable portions of the stem for pignut, shagbark, and bitternut in the Ohio Valley. This table shows the striking contrast between the proportion of sapwood produced by pignut and by the other two species.

TABLE 11.—*Proportion of heartwood, sapwood, and bark; second growth, Ohio Valley.*

Diameter breast-high.	Pignut.			Shagbark.			Bitternut.		
	Heart-wood.	Sap-wood.	Bark.	Heart-wood.	Sap-wood.	Bark.	Heart-wood.	Sap-wood.	Bark.
Inches:	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
5	0.0	78.0	22.0	0.0	80.0	20.0	17.0	66.0	17.0
6	2.0	76.5	21.5	3.5	77.0	19.5	22.0	61.5	16.5
7	4.0	75.0	21.0	7.0	74.0	19.0	27.0	57.0	16.0
8	6.0	73.5	20.5	11.0	70.5	18.5	31.0	53.0	16.0
9	8.0	72.0	20.0	15.0	67.0	18.0	36.0	48.5	15.5
10	10.5	70.0	19.5	19.0	63.0	18.0	40.5	44.1	15.5
11	13.0	68.0	19.0	23.0	59.5	17.5	44.5	40.0	15.0
12	15.5	66.0	18.5	27.0	56.0	17.0	49.0	36.5	14.5
13	18.0	64.0	18.0	31.0	52.5	16.5	52.5	33.5	14.5
14	20.5	61.5	18.0	35.0	49.0	16.0	55.5	30.5	14.0
15	23.5	59.0	17.5	39.0	45.5	15.5	58.0	28.0	14.0
16	26.5	56.5	17.0	46.0	39.0	15.0	60.5	26.0	13.5

The form of the stem is shown in Table 12, based on the measurements of 630 trees. Although the form varies somewhat with different species and again with different regions, the table makes it possible to compare the general form of the hickories with that of other trees; this comparison brings out its extremely slender, slightly tapering stem. The practical value of the table is to supply missing measurements. Thus if the diameter breast-high alone were known, the diameter 15 or 20 feet above the ground could be estimated with some degree of accuracy, or the diameter breast-high could be determined from that of the stump.

TABLE 12.—*Taper of stem of hickories.*

Diameter breast-high—inches.	Height—feet.								
	1.	2.	3.	4.	5.	10.	20.	30.	40.
	Diameter outside bark—inches.								
1	2.7	2.0	1.5	1.1	0.9	0.2	.....	.....	.....
2	3.8	3.1	2.5	2.1	1.9	1.2	.....	.....	.....
3	4.9	4.2	3.6	3.1	2.9	2.2	0.8	.....	.....
4	6.0	5.2	4.6	4.2	3.9	3.1	2.0	0.1	.....
5	7.1	6.3	5.6	5.2	4.9	4.3	3.2	1.5	.....
6	8.2	7.4	6.7	6.2	5.9	5.4	4.3	2.9	0.9
7	9.3	8.4	7.7	7.2	6.9	6.3	5.3	4.0	2.1
8	10.4	9.4	8.7	8.2	7.9	7.3	6.2	5.0	3.2
9	11.5	10.5	9.7	9.2	8.9	8.2	7.2	6.0	4.3
10	12.5	11.6	10.7	10.2	9.9	9.1	8.1	6.9	5.4
11	13.7	12.6	11.8	11.2	10.8	10.1	9.0	7.9	6.5
12	14.9	13.6	12.7	12.2	11.9	11.0	10.0	8.9	7.5
13	15.9	14.8	13.8	13.2	12.9	12.0	10.9	9.9	8.7
14	17.1	15.7	14.8	14.2	13.8	12.9	11.9	10.9	9.8
15	18.1	16.8	15.9	15.3	14.8	13.9	12.8	11.8	10.7
16	19.2	17.8	16.9	16.3	15.8	14.8	13.7	12.8	11.8
17	20.4	19.0	18.0	17.3	16.8	15.7	14.7	13.8	12.9
18	21.4	20.1	19.1	18.3	17.8	16.6	15.6	14.8	13.9
19	22.5	21.2	20.1	19.3	18.7	17.6	16.5	15.7	14.8
20	23.7	22.1	21.0	20.3	19.7	18.5	17.5	16.7	15.8
21	24.7	23.1	22.0	21.3	20.7	19.5	18.4	17.7	16.8
22	25.9	24.2	23.0	22.5	21.8	20.4	19.3	18.6	17.7
23	27.0	25.3	24.1	23.3	22.7	21.4	20.2	19.5	18.6
24	28.0	26.3	25.2	24.3	23.7	22.4	21.0	20.3	19.4
25	29.2	27.4	26.1	25.3	24.7	23.3	21.8	21.1	20.2
26	30.4	28.4	27.1	26.3	25.7	24.3	22.7	21.7	20.8
27	31.6	29.4	28.1	27.3	26.7	25.3	23.5	22.5	21.6
28	32.6	30.4	29.2	28.3	27.8	26.2	24.2	23.2	22.3
29	33.7	31.6	30.2	29.3	28.7	27.2	25.0	23.9	23.0
30	35.1	32.7	31.3	30.4	29.8	28.1	25.8	24.6	23.6
31	36.2	33.9	32.4	31.4	30.7	29.0	26.6	25.2	24.3
32	37.5	35.0	33.4	32.4	31.7	29.9	27.3	25.8	24.9
33	38.6	36.1	34.5	33.4	32.6	30.7	28.1	26.5	25.5
34	39.8	37.2	35.5	34.4	33.7	31.6	28.8	27.2	26.2
35	41.2	38.5	36.7	35.4	34.6	32.4	29.5	27.8	26.8
36	42.5	39.8	37.9	36.4	35.7	33.4	30.3	28.4	27.4

TABLE 12.—*Taper of stem of hickories*—Continued.

Diameter breast-high—inches.	Height—feet.								
	50.	60.	70.	80.	90.	100.	110.	120.	130.
	Diameter outside bark—inches.								
1	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	.....	.....	.....	.....	.....	.....	.....	.....	.....
3	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	.....	.....	.....	.....	.....	.....	.....	.....	.....
8	1.2	.....	.....	.....	.....	.....	.....	.....	.....
9	2.4	0.3	.....	.....	.....	.....	.....	.....	.....
10	3.5	1.5	.....	.....	.....	.....	.....	.....	.....
11	4.7	2.7	0.4	.....	.....	.....	.....	.....	.....
12	5.9	3.9	1.6	.....	.....	.....	.....	.....	.....
13	7.1	5.1	2.9	0.4	.....	.....	.....	.....	.....
14	8.3	6.3	4.1	1.6	.....	.....	.....	.....	.....
15	9.4	7.5	5.4	2.9	0.2	.....	.....	.....	.....
16	10.5	8.8	6.6	4.1	1.4	.....	.....	.....	.....
17	11.6	9.9	7.8	5.3	2.6	.....	.....	.....	.....
18	12.7	10.9	9.0	6.5	3.8	0.8	.....	.....	.....
19	13.7	12.1	10.1	7.6	4.8	1.8	.....	.....	.....
20	14.7	13.0	11.1	8.7	5.8	2.8	.....	.....	.....
21	15.7	14.1	12.1	9.8	6.9	3.8	0.5	.....	.....
22	16.6	15.0	13.1	10.8	8.0	4.9	1.6	.....	.....
23	17.4	15.9	14.0	11.7	8.9	5.8	2.4	.....	.....
24	18.2	16.8	14.9	12.6	9.7	6.5	3.1	.....	.....
25	19.1	17.6	15.7	13.5	10.6	7.4	3.9	0.3	.....
26	19.8	18.4	16.5	14.3	11.5	8.3	4.7	1.0	.....
27	20.5	19.1	17.3	15.0	12.3	9.2	5.6	1.6	.....
28	21.3	19.9	18.0	15.8	13.1	9.9	6.3	2.3	.....
29	22.0	20.6	18.8	16.5	13.9	10.8	7.0	2.8	.....
30	22.6	21.3	19.5	17.2	14.6	11.4	7.7	3.4	.....
31	23.3	22.0	20.3	18.0	15.3	12.1	8.3	3.9	.....
32	23.9	22.7	21.0	18.7	15.9	12.6	8.8	4.4	.....
33	24.5	23.2	21.6	19.4	16.6	13.3	9.3	4.9	0.1
34	25.1	23.8	22.2	20.1	17.2	13.9	10.0	5.4	.5
35	25.7	24.4	22.8	20.6	17.8	14.4	10.4	5.9	.9
36	26.4	25.1	23.5	21.3	18.4	14.9	10.9	6.3	1.3

Table 13 shows contents, in cubic feet, of logs of different lengths by diameters at the small end. It is based upon the taper measurements given in Table 12. It is an accurate log rule and can be used equally well in buying and selling large and small logs, and spoke and handle or pole and shaft or sucker-rod material. The Forest Service in Bulletin 36, "The Woodsman's Handbook," recommends that all log rules should be standardized by computations based on the diameter at the middle of the log. In the case of hickory, however, the rule based on diameters at the small end has some advantages.

TABLE 13.—*Log rule for hickory, giving contents in cubic feet.*

Diameter at small end of log—inches.	Length of log—feet.									
	2.	2.5.	3.	3.5.	4.	5.	6.	7.	8.	9.
	Volume [a]—cubic feet.									
4	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.8	0.9	1.0
5	.3	.4	.4	.5	.6	.8	1.0	1.2	1.4	1.5
6	.4	.5	.6	.8	.9	1.1	1.3	1.6	1.9	2.1
7	.6	.7	.9	1.0	1.2	1.5	1.8	2.2	2.5	2.8
8	.7	.9	1.1	1.3	1.5	1.9	2.3	2.8	3.2	3.6
9	.9	1.2	1.4	1.7	1.9	2.4	2.9	3.4	4.0	4.5
10	1.1	1.4	1.7	2.0	2.3	3.0	3.5	4.2	4.9	5.5
11	1.3	1.7	2.1	2.4	2.8	3.6	4.3	5.1	5.9	6.6
12	1.6	2.0	2.4	2.9	3.3	4.2	5.0	6.0	6.9	7.8
13	1.9	2.4	2.9	3.4	3.9	4.9	5.9	7.0	8.1	9.1
14	2.2	2.8	3.3	3.9	4.5	5.7	6.8	8.0	9.3	10.5
15	2.5	3.2	3.8	4.5	5.1	6.5	7.8	9.2	10.6	11.9
16	2.8	3.6	4.3	5.1	5.8	7.3	8.8	10.4	12.0	13.5
17	3.2	4.0	4.8	5.7	6.5	8.3	9.9	11.7	13.5	15.2
18	3.6	4.5	5.4	6.4	7.3	9.2	11.1	13.1	15.1	17.0
19	4.0	5.0	6.0	7.1	8.1	10.3	12.3	14.5	16.8	18.9
20	4.4	5.6	6.7	7.9	9.0	11.4	13.6	16.0	18.5	20.8
21	4.9	6.1	7.4	8.7	9.9	12.5	15.0	17.7	20.4	22.9
22	5.3	6.7	8.1	9.5	10.9	13.7	16.4	19.3	22.3	25.1
23	5.8	7.3	8.8	10.4	11.8	14.9	17.9	21.1	24.3	27.3
24	6.3	8.0	9.6	11.3	12.9	16.2	19.5	22.9	26.4	29.7

Diameter at small end of log—inches.	Length of log—feet.								
	10.	11.	12.	13.	14.	15.	16.	17.	18.
	Volume [a]—cubic feet.								
4	1.2								
5	1.8	2.0	2.2	2.5	2.7				
6	2.5	2.8	3.0	3.4	3.7	4.0	4.4	4.8	5.2
7	3.2	3.7	4.0	4.4	4.9	5.2	5.7	6.2	6.8
8	4.1	4.6	5.1	5.6	6.2	6.6	7.2	7.9	8.5
9	5.1	5.8	6.3	7.0	7.6	8.2	8.9	9.7	10.4
10	6.3	7.0	7.6	8.4	9.2	9.9	10.8	11.6	12.6
11	7.5	8.4	9.1	10.0	11.0	11.8	12.8	13.8	14.9
12	8.8	9.8	10.7	11.8	12.9	13.8	15.0	16.2	17.4
13	10.2	11.4	12.5	13.7	15.0	16.0	17.3	18.7	20.1
14	11.8	13.2	14.3	15.7	17.2	18.4	19.9	21.4	23.0
15	13.4	15.0	16.3	17.9	19.5	20.9	22.6	24.3	26.1
16	15.2	16.9	18.5	20.3	22.1	23.6	25.5	27.4	29.4
17	17.1	19.0	20.7	22.7	24.7	26.5	28.6	30.7	32.9
18	19.1	21.2	23.1	25.3	27.6	29.5	31.8	34.2	36.6
19	21.2	23.5	25.7	28.1	30.6	32.7	35.3	37.8	40.5
20	23.4	26.0	28.3	31.0	33.7	36.1	38.9	41.7	44.6
21	25.7	28.5	31.1	34.0	37.0	39.6	42.6	45.7	48.8
22	28.1	31.2	34.0	37.2	40.4	43.3	46.6	49.9	53.3
23	30.6	34.0	37.1	40.5	44.0	47.1	50.7	54.3	58.0
24	33.3	36.9	40.3	44.0	47.7	51.1	55.0	58.9	62.8

[a] This table is computed on an average taper of 1 inch in 7 feet, used length, which is a maximum for small trees, but very conservative for medium and large sized trees. In computing this average taper the rapid taper below the 5-foot point was excluded.

YIELD.

Yield tables show how much wood a given species will produce to the acre at different ages. In connection with tree values, these tables enable the intelligent woodlot owner to tell what trees it will pay him best to grow. Longleaf pine, for instance, produces a stronger and more valuable wood than loblolly pine and has the additional advantage of producing resin in merchantable quantities, but it is slower growing, and the yield per acre at the end of fifty or eighty or one hundred years is less than that from loblolly. Consequently he regards the loblolly as the better tree, and on soils which are suited to it he favors it over the longleaf. Similarly, conifers, such as pine, spruce, and Douglas fir, are a more profitable crop than broad-leaf trees, such as oak, ash, and black walnut, because their greater yield more than offsets the lower value of the wood. The yield per acre per year, under similar conditions of soil and climate and in stands of equal age and density, should be constant for a given species and often will differ greatly from that of other species. The determination of yield is of most importance for trees, such as pine and spruce, that grow naturally in pure, even-aged stands, but even in the case of hickories, which usually grow in mixture with other species, computations of yield per acre offer comparisons with other species and indicate how well the hickories utilize the space which they occupy.

In computing yields it is necessary to know not only the size of the trees, but also how many there are per acre. The best way to determine these two points is by actual measurement of pure, even-aged stands of different ages. Such measurements of 30 plots, with an average area of one-fourth acre, in several regions and for various species, showed the average yields of pure, even-aged stands of hickory at different ages to be as given in Table 14.

TABLE 14.—*Average yield of hickory per acre.*

Age.	Average diameter breast-high.	Average height.	Trees.	Total volume.	Merchantable volume.
Years:	*Inches.*	*Feet.*	*Number.*	*Cubic feet.*	*Cubic feet.*
30	4.0	33	700	800	100
40	5.0	41	480	1,100	300
50	6.2	49	320	1,400	500
60	7.2	57	230	1,700	700
70	8.1	64	180	2,000	850
80	9.0	69	155	2,300	1,000
90	9.8	74	135	2,600	1,150
100	10.5	78	120	2,900	1,300
120	11.8	85	100	3,500	1,650
150	13.4	92	75	4,400	2,000
200	19.0	100	65	5,700	2,700

It will be noted, first, that the average diameters, except during the earlier years, fall below those given for shagbark and pignut in Table 4. This is because the stands in many cases were too dense,

so that the growth had become very slow. Under management which should aim to secure rapid growth and strong wood the stands should be thinned, and thus opened up. This means that after the fiftieth year there would be fewer trees than is indicated in the table, but their growth would be hastened. The total volume increase is 300 cubic feet each decade, or an average yield of 30 cubic feet a year. This is a safe estimate for fully stocked stands on soils of moderate fertility. Two sprout stands in Ohio 22 and 45 years old, on very good soil, showed a yield of 44 cubic feet a year, while three seedling stands 200 years old on river bottoms in the South showed a yield of 36 cubic feet a year. The minimum yield from dry situations and on shallow soils was 15 cubic feet. There was no difference discovered in the yields of shagbark, pignut, and mockernut.

The fact that the heaviest yields were produced by stands of sprout origin, while not conclusive, indicates that sprout stands may be expected to produce heavier yields than seedling stands under short rotations. This is of great importance in deciding upon the method of management.

While conclusive figures on the yield of the important American hard woods is lacking, there are enough to make general comparisons possible. Studies made by the Forest Service in Illinois show that catalpa makes an annual average growth of 1.35 cords per acre; black walnut, 0.90 cord; ash, 0.89 cord; and osage orange, 0.54 cord; in Maryland and Virginia, yellow poplar, 1.1 cords; and in southern New England, chestnut, about 1 cord, and mixed oak and chestnut sprouts from one-half to three-fourths of a cord. Catalpa, moreover, is ready to market in twenty years, and chestnut in from thirty to sixty. These figures are rough and must be taken with considerable allowance, but even with due allowance the comparison is very unfavorable to hickory, because the other important commercial hard woods produce more merchantable material and some of them mature in a much shorter time.

THE WOOD AND ITS MECHANICAL PROPERTIES.

The technical qualities of the wood are, in cases of the hickories, of first importance. It is to its toughness, strength, and elasticity almost entirely that the hickory owes its value. It is therefore important to know to what extent it is actually superior to other woods like oak, maple, or eucalyptus, and also which of the different species are most valuable, and under what silvical conditions the best timber may be produced. It is also important to know the range of strength and toughness of different kinds of hickory, so as to be able to distinguish good hickory from poor hickory by its physical characteristics, and to know from what parts of the tree the best wood usually can be secured.

HICKORY TESTS.

To answer these questions a series of tests was undertaken at the Forest Service laboratory at Purdue University.

DESCRIPTION OF MATERIAL.

The material was secured from 4 different localities and includes 7 different species.

Hickory from the South.—Thirty-three trees were secured from Sardis, Miss. Of these, 4 trees were shagbarks, 4 pignuts, 8 mockernuts, 10 big shellbarks, 10 nutmeg hickories, and 2 water hickories.

The soil conditions were typical of the Mississippi Delta region. The land is low and flat, water stands in pools during the winter months, and the ground is moist or wet the year round; the soil is a rich, sandy loam underlain by clay. The forest is composed chiefly of cow oak, willow oak, red gum, elm, ash, and shagbark, pignut, and mockernut hickories. Water hickory and big shellbark are more scattering and are confined to the moist situations. Mockernut is a small tree that grows on dry situations and does not figure prominently in the southern cut.

The trees included in this southern shipment were comparatively large and overmature and typical of the region. They were mostly from 200 to 300 years old and about 28 inches in diameter and from 100 to 120 feet in height, except the big shellbarks, which averaged about 16 inches in diameter and about 95 feet in height. Water and nutmeg hickories are common enough but are scarcely cut at all in the South, because of their recognized inferiority.

Like most of the southern hickory, this material was comparatively clear, but had many wormholes, and in drying became shaky, especially the nutmeg and water hickories. The trees were cut in October and shipped in November.

Hickory from Ohio.—Forty trees were secured near Napoleon, Ohio. Of these, 10 were shagbarks, 10 pignuts, 9 big shellbarks, and 11 bitternuts.

The soil conditions here are typical of the lake region of northern Indiana and Ohio. The land is low, flat, and poorly drained, with a sandy soil underlain by clay; there is hardpan at a depth of from 6 to 8 feet. This land must be drained before it can be successfully farmed. The trees in mixture were elm, white ash, white, bur, and red oaks, and shagbark, big shellbark, pignut, and bitternut hickories.

The pignut grew on the better-drained lands and the bitternut and big shellbark on moist ground. The shagbark and pignut were typical of the trees being cut in this region and were of average quality, with ages ranging from 65 to 220 years. The diameter at

breastheight was from 5 to 21 inches and the total height from 60 to 80 feet. The big shellbarks were about 130 years old, 11 inches in diameter breast-high, and 60 feet in height, and would all be classed as the finest second growth. The bitternuts were from 65 to 100 years old, 9 to 17 inches in diameter, and from 65 to 95 feet high. They were all young, rapid-growing trees and much superior in this respect to the shagbark and pignut.

The trees were cut during October and November and were shipped December 1. In both the Mississippi and Ohio shipments each tree was selected in the woods. Its diameter and height were measured, and the soil and other conditions were carefully described.

Hickory from West Virginia.—Thirty trees were obtained from Holly, Webster County, W. Va.—10 shagbarks, 19 pignuts, and 1 mockernut. The soil conditions here are typical of much of the Southern Appalachians. The altitudes are from 900 to 1,800 feet and the slopes very steep. The hickories cut here are mostly large, overmature trees from the east and north slopes, where they grow with white oak, yellow poplar, basswood, buckeye, maple, and red and black ash. Of this shipment, 12 typical trees—7 shagbarks and 5 pignuts—were selected in the yard. The ages were from 100 to 350 years, the diameters from 14 to 24 inches. Some of the logs were shaky, but not so much so as in the southern hickories.

The other 18 trees were cut by the Forest Service, and soil and silvical conditions were carefully described in the case of each tree. Of these trees, 3 shagbarks and 9 pignuts represent northern and eastern slopes. The trees ranged from 45 to 220 years old, 9 to 16 inches in diameter, and from 65 to 100 feet high, and they are better than most of the hickory which is being cut in this locality. The material from these trees would be considered strictly second growth. Five pignuts and 1 mockernut came from a dry, steep, rocky slope where, because of extremely unfavorable conditions the growth is slow and stunted. These trees were from 140 to 230 years old, 8 to 10 inches in diameter, and from 50 to 60 feet high.

The cutting was done in February and March, and the material was shipped March 15, 1908.

Hickory from Pennsylvania.—Thirty-nine trees were obtained in Chester County, Pa. Of these, 27 were pignuts, including 2 distinct varieties, the true pignut and the small-fruited pignut, 11 were mockernuts, and 1 was shagbark. The soil was fresh, sandy loam, of excellent quality, splendidly suited for agriculture. The region is a long-settled one and the woodlots have been culled over for many years, so that conditions have been most favorable for good growth. The trees in mixture with the hickories in this region are white, red, and black oak, chestnut, and white ash.

Two pignuts and 6 mockernuts came from eastern Maryland and were selected in the yard. The other trees were obtained from 4 different woodlots.

The material is typical of the hickory cut in this locality. In age it ranges from 70 to 240 years, but most of the trees are from 150 to 200 years old, with diameters of from 14 to 20 inches, and heights of from 80 to 100 feet.

The cutting was done in March. The material was shipped partly in April and partly in May.

CARE OF MATERIAL.

From each of these trees 1 flitch was cut through the center of the butt log from bark to bark. The flitches were 4 inches thick and from 7 to 12 feet long, depending on the length of the log. From a few trees flitches were secured from the upper logs, and the entire merchantable boles of two pignuts from Pennsylvania were used to determine the strength as affected by height in the tree.

Upon arrival at the laboratory the flitches were cut into sticks 2½ by 2½ by 30 inches, and the specimens intended for green tests were immersed in water until the time of test to preserve them in the green condition. The temperature of the wood at the time of test was about the same for all specimens, so that the relative strength would not be affected by this cause. Shortly before the time of test the specimens were removed from the water, planed to 2 by 2 inches, and sawed to a uniform length of 28 inches for the bending test. After the bending test specimens were cut from the uninjured portion of the beam for other tests.

In cutting the individual test pieces from the flitches no attempt was made to select pieces which might yield the highest results. However, specimens were selected so as to avoid shakes and culls and to include the various kinds of growth found in any given flitch, and specimens that contained visible defects which would certainly lower the strength were not included in the tests.

METHODS OF TEST.[a]

The specimens were all accurately measured and weighed, the per cent of sapwood measured, and the number of rings per inch counted. The nonporous part of the annual rings was measured and its proportion given in per cent of the whole growth; the moisture content was determined in per cent of oven-dry weight.

Static bending tests are the most important of the tests made.

Beams 2 inches square and 28 inches long were supported on knife edges 26 inches apart. Plates and rollers were used to avoid crushing

[a] The methods of test were those described in Circular 38, Forest Service, entitled "Instructions to Engineers in Timber Tests."

the specimen and to do away with any friction at the end bearings. The load was applied at the center by a screw testing machine. The moving head of the machine descended at a uniform speed of 0.09 inch per minute. The amount of bending was noted for each 100 pounds increase in load up to the point where the stick began to give away, after which the loads were read for each 0.1 inch increase in deflection. The load bending curve was platted at the time of test, and the load and deflection were recorded at first visible failure and at maximum load.

The following points were determined: Specific gravity as tested and oven dry, weight per cubic foot as tested and oven dry, fiber stress at elastic limit, modulus of rupture, modulus of elasticity, horizontal shear at maximum load, work or resilience to elastic limit, work to maximum load, and total work.

Of these, the most important, in the consideration of a timber like hickory, are the strength at maximum load, as shown by the modulus of rupture, and work to maximum load.

Strength at maximum load is a measure of the ability of the timber to hold a load applied without shock.

Work to maximum load is a measure of the ability of the timber to withstand a shock or blow or any very suddenly applied load. It is a measure of toughness.

Other tests were also made in compression parallel to the grain, compression perpendicular to the grain, shear, abrasion, shrinkage, impact, and torsion.

HICKORY WOOD AS COMPARED WITH OTHERS.

None of the pines or other conifers compare with hickory in strength and toughness.

Of the broad-leaf trees, some varieties of eucalyptus have about the strength of good hickory, but the grain is locky and the wood hard to work; furthermore, they have not the toughness of hickory, especially in the small sizes, where the locky grain might cause failure.

Hard maple wagon axles are more nearly comparable to hickory than those of any other wood. Hard maple has about the strength of hickory, though it is somewhat inferior in toughness. For this use hard maple would be a good substitute for hickory, except for the fact that it is likely to have twisted or spiral grain. White oak is too useful for other purposes to be considered as a substitute for hickory at the present time. Moreover, it is somewhat inferior to hickory in strength and toughness. Red oak, carefully selected, may be used as a substitute for the poorer grades of hickory. Ash also may be substituted for hickory in some of its uses. While

buggy wheels have been made of catalpa, this wood will never replace hickory, because it has only about one-half the strength of good hickory.

No timber has been found which has both the strength and shock-resisting qualities of hickory. This is especially true of small materials, such as rims, spokes, and ax handles.

FACTORS THAT AFFECT STRENGTH.

MOISTURE.

Table No. 15 shows the effects of moisture on strength. The strength at maximum load represented by the modulus of rupture is about doubled by drying, and the shock-resisting ability, or work to maximum load, is slightly decreased, due to the great decrease in bending of the dry material.

TABLE 15.—*The effect of moisture on strength of hickory from all localities.*

Species.		Per cent of moisture.	Specific gravity, dry.	Modulus of rupture.	Work to maximum load.
	Green.				
				Pounds per sq. in.	
Pignut	Average	55.4	0.664	11,455	33.0
	High 10 per cent	70.6	.731	14,538	60.0
	Low 10 per cent	45.2	.591	8,192	16.9
Shagbark	Average	62.0	.637	10,561	22.4
	High 10 per cent	75.0	.700	13,009	54.1
	Low 10 per cent	49.3	.573	8,000	8.2
Mockernut	Average	57.3	.622	11,177	30.5
	High 10 per cent	82.5	.703	13,370	59.7
	Low 10 per cent	47.2	.521	7,911	9.1
Big shellbark	Average	59.3	.639	10,340	34.5
	High 10 per cent	85.8	.702	13,988	42.2
	Low 10 per cent	45.3	.521	7,737	11.9
	Air dry.				
Pignut	Average	9.5	0.776	23,482	31.2
	High 10 per cent	10.3	.862	27,804	52.5
	Low 10 per cent	8.6	.648	16,563	13.2
Shagbark	Average	9.7	.742	22,148	27.8
	High 10 per cent	10.5	.811	26,760	47.8
	Low 10 per cent	9.2	.666	17,953	11 7
Mockernut	Average	9.3	.723	20,370	22.1
	Maximum	11.2	.821	25,120	37.8
	Minimum	8.2	.666	15,370	9.6
Big shellbark	Average	9.3	.736	19,724	23.6
	Maximum	10.4	.801	25,320	38.2
	Minimum	8.4	.627	16,070	6.2

WEIGHT.

Figure 12, which includes all the commercial hickories, shows that the work or shock-resisting ability increases in proportion to the dry weight of the wood. The strength at maximum load also appears to increase almost in direct proportion to the dry weight. The deduc-

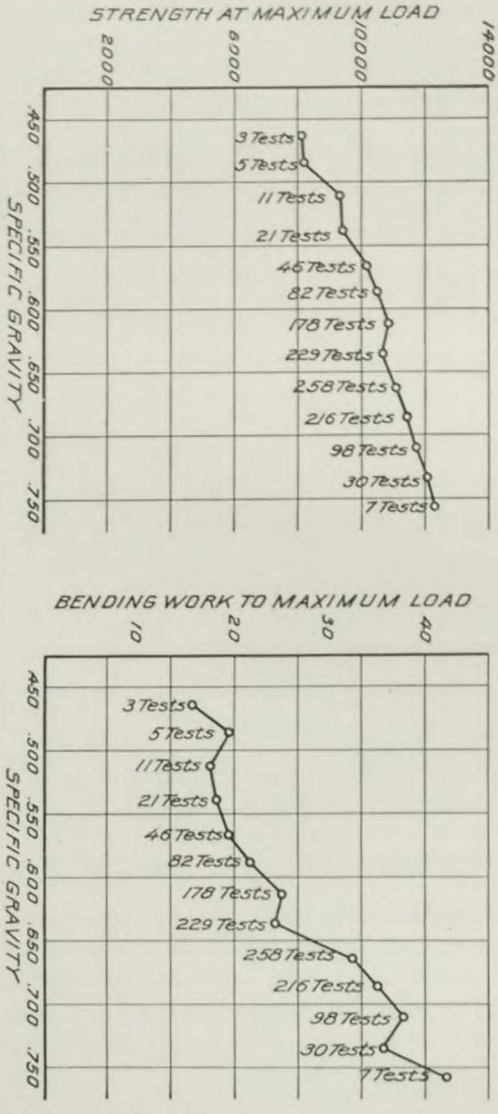

FIG. 12.—Strength and work as affected by specific gravity, as shown by tests on green hickory.

tion from figure 12 is that hickory may be inspected upon a basis of weight, and the heavier the wood the better. Additional confirmation of this is found in figure 13,[a] which shows that the strength and

[a] From Forest Service Circular No. 142, "Tests of Vehicle and Implement Woods."

resilience of spokes increase with the weight of the spoke. This relation of weight to strength is true of various species, as is shown clearly in Circular 15 of the Division of Forestry [a] and confirmed by many more recent tests.

RATE OF GROWTH.

Usually woods are selected on the basis of appearance, very largely on the rate of growth, as shown in the cross section. In hickory the wide-ringed wood, often called "second-growth" hickory, is preferred. Figure 14, based on commercial hickory grown in good situ-

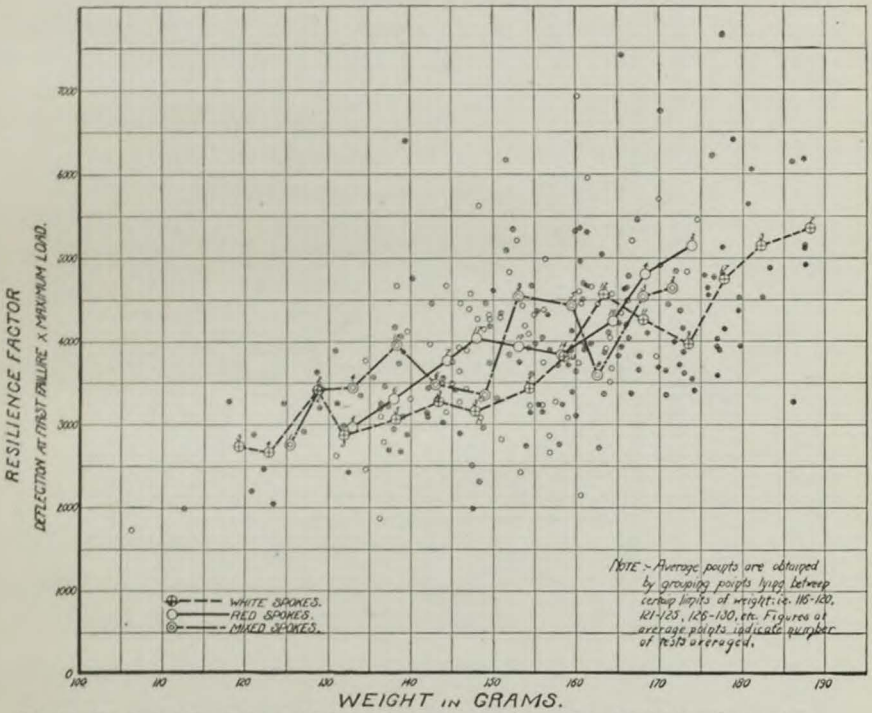
RESILIENCE FACTOR
DEFLECTION AT FIRST FAILURE X MAXIMUM LOAD.
WEIGHT IN GRAMS.
WHITE SPOKES.
RED SPOKES.
MIXED SPOKES.
NOTE - Average points are obtained by grouping points lying between certain limits of weight: i.e. 116-120, 121-125, 126-130, etc. Figures at average points indicate number of tests averaged.

FIG. 13.—Spoke-test chart, showing relation between resilience factor and weight in clear spokes.

ations, shows that the work or shock-resisting ability is greatest with wide-ringed wood that has from 5 to 14 rings per inch; is fairly constant from 14 to 38 rings, and decreases rapidly from 38 to 47 rings per inch. The strength at maximum load is not so great with the most rapid-growing wood; it is at a maximum with from 14 to 20 rings per inch, and again becomes less as the wood becomes more closely ringed.

The natural deduction is that wood of first-class mechanical value shows from 5 to 20 rings per inch, and that slower growth yields poorer

[a] Summary of Mechanical Tests upon Thirty-two Species of American Woods.

stock. Thus the inspector or buyer of hickory should discriminate against timber that has more than 20 rings per inch. Exceptions

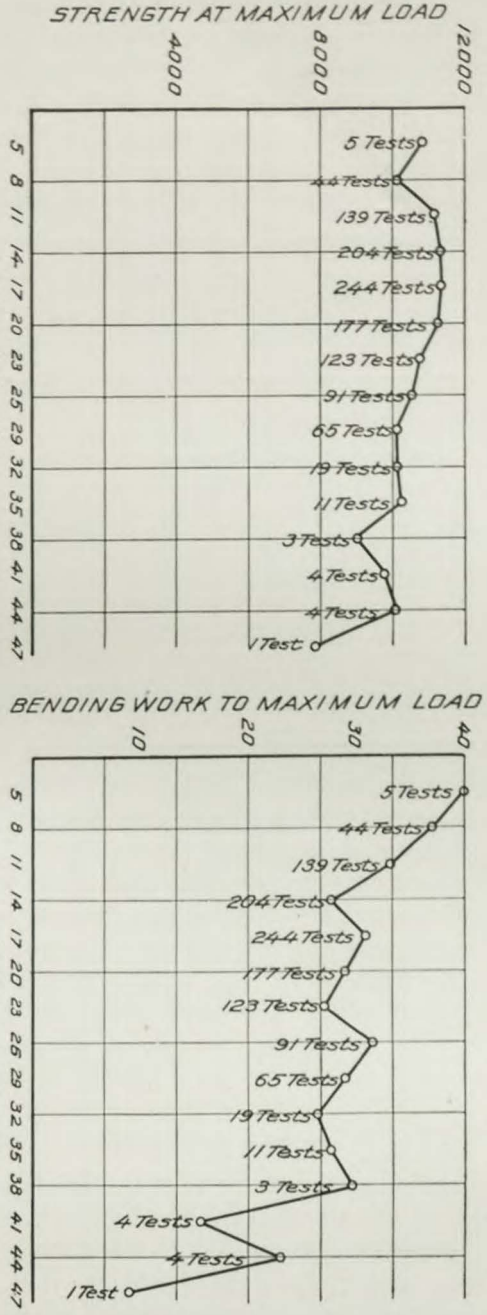

Fig. 14.—Strength and work as affected by rate of growth, as shown by tests on green hickory.

exist, however, in the case of normal growth upon dry situations, in which the slow-growing material may be strong and tough.

HEARTWOOD AND SAPWOOD.

In the case of the hickories there is an unfounded prejudice against the heartwood. Specifications place white hickory, or sapwood, in a higher grade than red hickory, or heartwood, though there is no inherent difference in strength. In fact, in the case of large and old hickory trees the sapwood nearest the bark is comparatively weak, and the best wood is in the heart, though in young trees of thrifty growth the best wood is in the sap.

TABLE 16.—*Comparative values of sapwood and heartwood in selected pieces of green pignut and shagbark, and in commercial hickories taken at random.*

Kind of wood.	Rings per inch.	Dry specific gravity.	Modulus of rupture.	Work to maximum load.
Selected pieces of pignut and shagbark.	*Number.*		*Pounds per square inch.*	*Inch pounds per cu. in.*
Heartwood (south)	19.5	0.628	11,800	22.4
Heartwood (north)	16.0	.683	10,600	31.2
Sapwood (south)	18.4	.599	11,130	20.2
Sapwood (north)	16.6	.664	12,160	33.1
Average heartwood	17.3	.667	11,070	28.1
Average sapwood	17.4	.639	11,790	28.5
Commercial hickory of several species.				
Heartwood (south)	22.0	.632	11,080	26.8
Heartwood (north)	20.9	.660	10,322	31.4
Sapwood (south)	19.0	.588	11,065	22.9
Sapwood (north)	15.0	.672	11,693	76.0
Average heartwood	21.0	.648	10,630	29.4
Average sapwood	17.0	.640	11,509	30.4

Table 16 gives the results of tests from selected pieces lying side by side in the same tree, and also the average values for heartwood and sapwood in shipments of the commercial hickories without selection. It shows conclusively that the transformation of sapwood into heartwood does not affect either the strength or toughness of the wood. This conclusion is also confirmed by Forest Service Circular 142, which shows that, weight for weight, sound hickory is equally strong, regardless of color. Therefore the user of hickory should not discriminate against heartwood in buying stock. It is true, however, that sapwood usually is more free from latent defects than heartwood.

POSITION IN THE TREE.

The determination of the strength of material at various distances from the center of the tree toward the bark gives a good indication of the effect of growth on strength. In trees from forests which have grown for a long time under fixed conditions it is necessary only to take a specimen from a predetermined point in the cross section at a given height to determine a factor which represents the mechanical

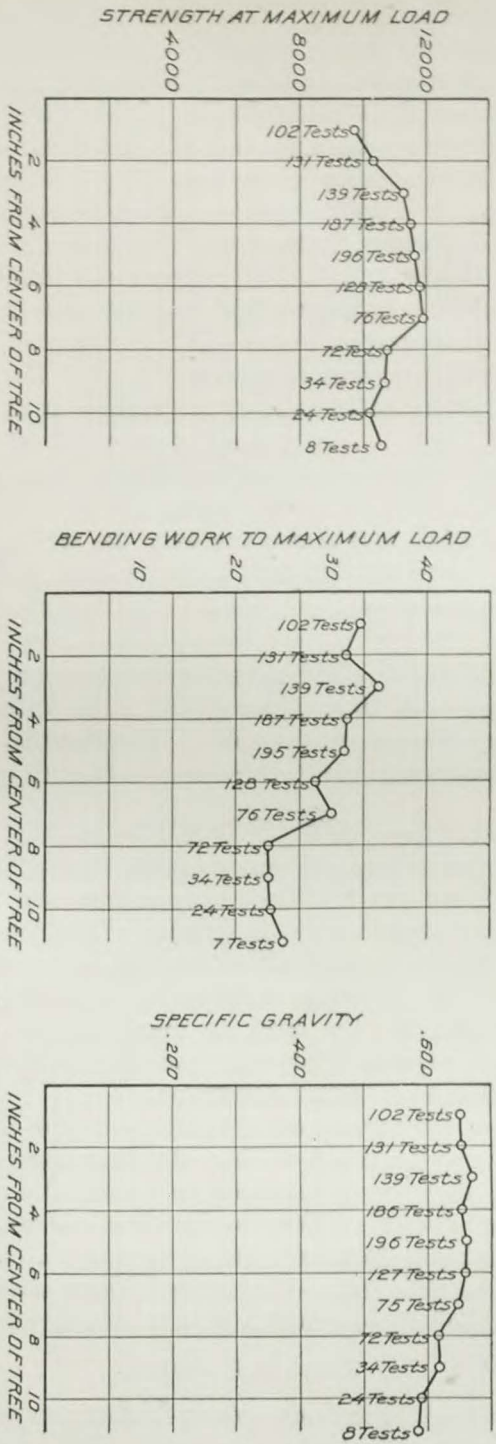

Fig. 13.—Strength, work, and specific gravity as affected by position in the tree, as shown by tests on green hickory.

value of the wood in the tree. This procedure is, however, not possible with American woods, because silvical conditions have not become constant, and the origin and history of the tree are unknown.

Figure 15 shows the results of tests to determine the strength in relation to the distance from the center of the tree. In normal trees, the strongest wood appears to be from 5 to 7 inches out from the center of the tree, and wood of greatest shock-resisting ability is nearly in the center; consequently the wood 3 to 7 inches from the center of the tree is the best. However, suppression and slow growth in youth, followed by exposure to light and fast growth in old age, will disturb these relations, and under such conditions the best wood may be found near the outer part of the tree.

The entire merchantable boles of two trees were used to determine the relation of height above ground to strength and toughness (see fig. 16). The butt cuts were toughest but not strongest; the strongest wood was from 21 to 30 feet above the ground. The toughest wood is in the butt, and above the butt the technical value of the wood remains practically constant up to the base of the crown, where it becomes less valuable..

AGE.

Trees about 150 years old have the maximum average strength, but the average work to maximum load is less with increasing age, and the youngest trees are toughest. Therefore, to obtain the best wood the trees should not be allowed to become overmature.

SOIL AND SITUATION.

In some regions there are many small, stunted hickories, which most users will not touch. They have narrow sap, are likely to be birdpecked, and show very slow growth. Yet five of these trees from a steep, dry south slope in West Virginia had an average strength fully equal to that of the pignut from the better situation, and were superior in toughness, the work to maximum load being 36.8 as against 31.2 for pignut. The trees had about twice as many rings per inch as others from better situations.

This, however, is not very significant, as trees of the same species, age, and size, growing side by side under the same conditions of soil and situation, show great variation in their technical value. It is hard to account for this difference, but it seems that trees growing in wet or moist situations are rather inferior to those growing on fresher soil; also, it is claimed by many hickory users that the wood from limestone soils is superior to that from sandy soils.

GEOGRAPHIC LOCATION.

One of the moot questions among hickory men is the relative value of northern and southern hickory. The impression prevails that southern hickory is more porous and brash than hickory from

the north. The tests summarized in Table 17 indicate that southern hickory is as tough and strong as northern hickory of the same age.

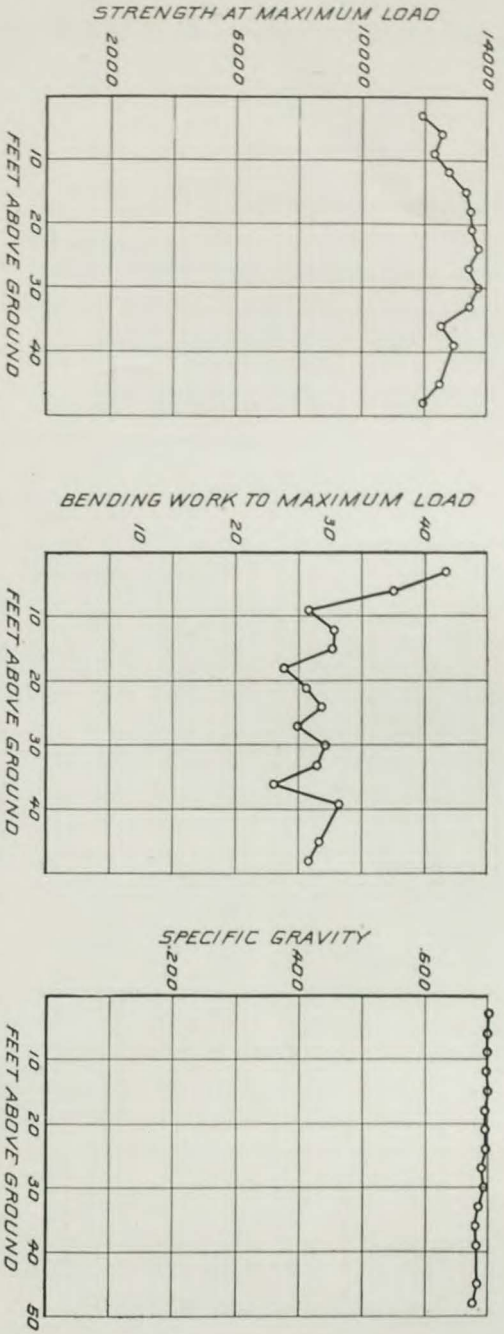

Fig. 16.—Strength, work, and specific gravity as affected by height above the ground in the tree, as shown by tests on green hickory.

But the southern hickories have a greater tendency to be shaky, and this results in much waste. In trees from southern river bottoms

the loss through shakes and grub holes in many cases amounts to as much as 50 per cent.

TABLE 17.—*Comparison of strength and toughness of northern and southern hickories of the same age.*

Location.	Number of trees.	Age.	Number of tests.	Rings per inch.	Specific gravity dry.	Modulus of rupture.	Work to maximum load.
				Number.		*Pounds per sq. in.*	*Inch pounds per cu. in.*
Southern hickories	8	260	120	18.2	0.621	11,544	24.1
Northern hickories	16	266	127	22.6	.637	10,581	22.8

TABLE 18.—*Summary of static bending tests of various hickories from several localities.*

Species.		Mississippi.				Ohio.			
		Per cent of moisture.	Dry specific gravity.	Modulus of rupture.	Work to maximum load.	Per cent of moisture.	Dry specific gravity.	Modulus of rupture.	Work to maximum load.
				Pounds per sq. in.	*Inch pounds per cu. in.*			*Pounds per sq. in.*	*Inch pounds per cu. in.*
Pignut	Average	60.2	0.628	11,800	26.8	54.1	0.661	11,820	31.4
	High 10 per cent.	77.5	.679	13,866	44.8	65.1	.713	14,430	58.2
	Low 10 per cent.	48.6	.560	9,880	12.2	46.0	.597	8,425	12.6
Shagbark	Average	64.5	.613	11,210	20.6	59.1	.648	10,610	34.4
	High 10 per cent.	77.5	.664	12,838	41.0	74.3	.707	13,225	59.9
	Low 10 per cent.	50.8	.562	8,755	8.7	49.5	.579	7,961	12.4
Mockernut	Average	63.8	.606	11,310	23.6	.....	.....	.....	.....
	High 10 per cent.	85.0	.676	13,038	52.8	.....	.....	.....	.....
	Low 10 per cent.	47.7	.510	8,462	8.6	.....	.....	.....	.....
Big shellbark	Average	63.5	.612	10,890	30.6	55.2	.667	9,790	38.5
	High 10 per cent.	82.0	.679	13,950	60.8	69.8	.729	11,896	55.5
	Low 10 per cent.	46.9	.514	7,805	10.5	47.6	.625	7,212	18.4
Bitternut	Average	.....	.....	.....	.....	65.6	.622	10,030	30.9
	High 10 per cent.	.....	.....	.....	.....	79.0	.658	12,622	58.6
	Low 10 per cent.	.....	.....	.....	.....	50.3	.573	7,463	8.3
Nutmeg hickory	Average	75.9	.567	9,200	23.9	.....	.....	.....	.....
	High 10 per cent.	93.0	.620	11,575	40.8	.....	.....	.....	.....
	Low 10 per cent.	61.0	.488	6,773	11.3	.....	.....	.....	.....
Water hickory	Average	75.5	.625	10,329	18.1	.....	.....	.....	.....
	High 10 per cent.	98.6	.720	11,966	30.8	.....	.....	.....	.....
	Low 10 per cent.	51.0	.552	8,893	8.9	.....	.....	.....	.....

Species.		West Virginia.				Pennsylvania.			
		Per cent of moisture.	Dry specific gravity.	Modulus of rupture.	Work to maximum load.	Per cent of moisture.	Dry specific gravity.	Modulus of rupture.	Work to maximum load.
				Pounds per sq. in.	*Inch pounds per cu. in.*			*Pounds per sq. in.*	*Inch pounds per cu. in.*
Pignut	Average	51.8	0.677	11,430	32.6	55.5	0.677	11,114	37.1
	High 10 per cent.	64.9	.746	15,000	59.7	69.7	.726	14,425	65.8
	Low 10 per cent.	43.9	.606	8,385	10.4	44.9	.595	7,920	9.4
Shagbark	Average	60.8	.656	10,770	18.8	63.7	.630	9,655	15.9
	High 10 per cent.	71.7	.696	13,131	40.9	.....	.....	.....	.....
	Low 10 per cent.	48.1	.585	7,837	6.2	.....	.....	.....	.....
Mockernut	Average	49.3	.666	12,120	32.6	58.7	.658	10,100	35.4
	High 10 per cent.	.....	.....	.....	.....	67.1	.728	14,132	59.6
	Low 10 per cent.	.....	.....	.....	.....	48.8	.584	7,338	13.6

In this connection, attention may be called to the low value of green, eastern shagbark, as shown in Table 18 and figure 17, as compared to that of Ohio and Mississippi. This is hard to explain, but corroborates the prejudice which some eastern users have against shagbark. Dry specimens do not show this inferiority.

A more thorough study will be necessary before definite conclusions can be drawn.

It is clear, therefore, that the difference in northern and southern hickory is not due to geographic location, but rather to the character of timber that is being cut. Nearly all of that from southern river bottoms and from the Cumberland Mountains is from large, old-growth trees; that from the north is from younger trees which are grown under more favorable conditions, and it is due simply to the greater age of the southern trees that hickory from that region is lighter and more brash than that from the north.

SPECIES.

According to Tables 15 and 18 and figure 17, pignut, which is generally considered best, is actually the strongest and toughest and is comparatively uniform for all regions. Shagbark is only slightly inferior to pignut; big shellbark is of only medium strength, but is inferior to no other species in toughness; mockernut is somewhat stronger than big shellbark, but lacks toughness.

The pecan hickories are very little used throughout the region where hickory is cut, and spoke and handle makers consider them inferior; the few tests which were made suffice at least to show that this prejudice is well founded. Bitternut from northern Ohio, which was of the best quality of second growth, is slightly inferior to other hickories from the same region. Nutmeg and water hickories are characteristically shaky, and the tests show that the wood is inferior to that of the true hickories.

Strength and toughness vary greatly within the same species. Thus, although pignut from Pennsylvania is very strong and tough, it will yield much material which is no better than the average of the poor species grown is less favorable localities. In general, the lowest grades of the best of the true hickories are no better than the average of the poorest pecan hickories. While, therefore, the different species have different average values—and this is an important consideration in forest management and in the buying of trees in the woods—the selection of the best hickory in the yard can not be based on anything but a most rigid inspection and grading. The pecan hickories all produce inferior timber, and true pecans, if grown for the commercial value of their fruits, should not be seedlings, but named varieties, grafted or budded.

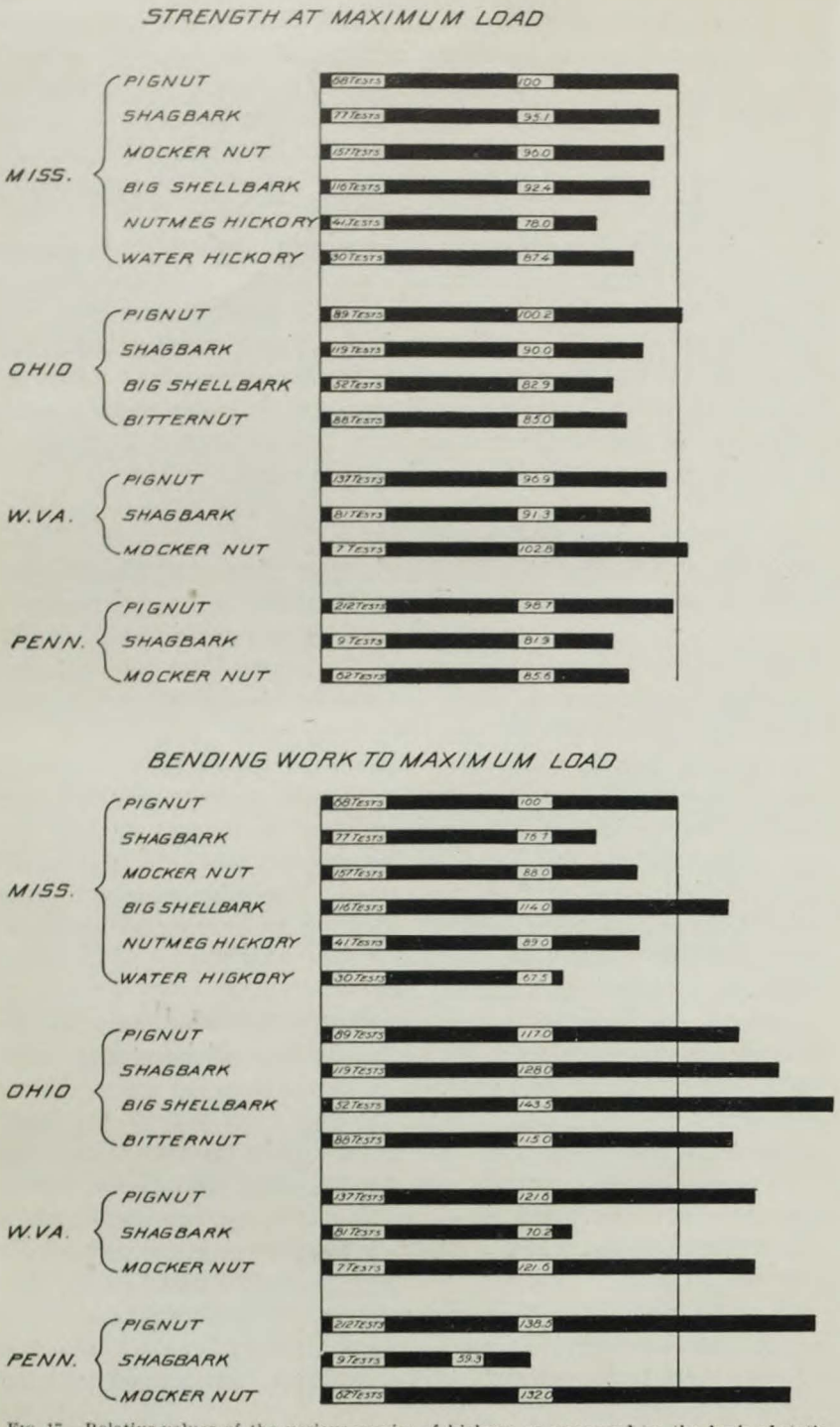

FIG. 17.—Relative values of the various species of hickory, as compared on the basis of static bending tests.

DEFECTS.

Iron streaks and birdpecks of small size do not appear to affect the strength or toughness of hickory. Hair checks are usually found in the heavier and better timber, and have but little effect upon the strength and toughness. Cross and spiral grain and dips in grain are all serious defects, and greatly reduce strength and toughness. The weakening effect of knots is due chiefly to the cross grain which they cause.

OUTLOOK FOR FUTURE SUPPLY.

A shortage in the hickory supply is imminent. Virgin hickory, which has hitherto furnished the chief supply, is disappearing rapidly, and there are no foreign sources which can be drawn upon when the home supplies are exhausted. It will soon be necessary, therefore, to depend entirely upon the second growth. The maintenance of the supply is of vital concern, because no satisfactory substitute has as yet been found.

Forest owners, with some justice, regard the hickories as inferior trees, but there is one important consideration in their favor; large sizes are not required. With oak, black walnut, black cherry, yellow poplar, and other important hardwood trees, there is a great increase in value with size, because the heartwood is most valuable and timber of large dimensions is needed. But with hickory, the only increase in value with size comes from the increased number or size of the clear billets or strips which can be obtained from a tree. Sapwood is now preferred to heartwood and the younger and faster-grown material is tougher than the older and the slower grown. For most of its uses hickory can be cut when it is 8 or 9 inches in diameter and from 40 to 60 years old, while oak generally must be from 18 to 20 inches in diameter and from 100 to 120 years old. Even hickory, however, can not be cut so early as can catalpa and black locust for fence posts, cottonwood and yellow poplar for pulp, chestnut for ties and poles, and white pine for box boards, and all of these grow faster than hickory. Moreover, the yield of hickory per acre, as is usual with trees which produce a hard, heavy wood, is comparatively low.

For similar sites and areas, the total volume production of white pine is at least three times that of hickory; of catalpa, yellow poplar, and chestnut at least twice as much as hickory; and of ash, black walnut, and white oak at least from one-third to one-half more. Then, too, the demands of the hickory trade are very exacting. Generally less than half the total volume is used, whereas, with white pine and other conifers the utilization is very close; in New England, for instance, more than 90 per cent of the total volume of white pine is used. Even the other hardwoods, such as chestnut, white ash, and yellow poplar, are utilized more closely than hickory. Yet present prices do not take these facts into account, and even at the compara-

tively high stumpage price of $10 a cord a fully stocked stand of hickory 50 years old is worth only about $80 an acre, while a white-pine stand of the same age at the low stumpage value of $5 per thousand, or approximately $2.50 a cord, would be worth $200. On rich soils catalpa has yielded more than $200 per acre at the end of twenty years. In short, it does not pay to raise hickory when it is possible to raise chestnut, catalpa, black walnut, or yellow poplar. Therefore, the forest owner who considers only present prices, and the slow growth and low yield per acre, is likely to cut out his hickories to make room for faster-growing species; and he will never plant hickory.

Prices, however, are bound to advance, because of the high technical value of hickory, coupled with the fast-diminishing supply. Current prices can advance considerably without affecting the trades. At present the stumpage values range from 2 to 33 per cent of the value of the finished product and average less than 10 per cent. The costs of manufacture and of transportation are still the largest item in the cost of a spoke or of a rim strip. Unless some entirely new material is found to take the place of hickory, and this seems quite improbable, it is only a question of time when the prices will advance sufficiently to place hickory on an equal footing with chestnut, poplar, and other faster-growing species; even now it is practically on an equal footing with white oak and white ash, the other trees most important for toughness and strength used for purposes similar to those for which hickory is used.

With the hickories on an even footing with other important timber trees, with the hardwood forests of the country under proper management, and with the drain decreased through a lessening of waste, there should be no difficulty in producing all the hickory that is needed for home consumption, with some over to supply much of the foreign demand.

There are now about 100,000,000 acres of forest land on which hickory is growing naturally, although not necessarily in pure stands. In most places the forest has been wastefully cut and severely burned and pastured, so that it is in a low productive condition. It must soon become the object of care and attention. Because of their naturally good reproduction, their ability to endure shade and to grow under many different conditions of soil and climate, the hickories are particularly amenable to forest management, and a little intelligent care can greatly better both quantity and quality of the yield.

METHODS OF PERPETUATING THE SUPPLY.

The two principal methods by which the supply can be maintained are economic and silvicultural. The first depends upon hickory users, and will consist in reducing waste and improving the economic

position of the tree; the second lies in the hands of the forest owners, and will consist in the proper care of the tree in the forests with a consequent increase in the quantity and betterment of the quality of the crop. User and producer must act together, for without a reduction of waste there will be too severe a tax on the hickory resources to produce enough timber even with special attention given to the production of a greater supply. Without an improvement in the economic position of the tree, no attention will be paid to the production of new supplies, and hickory will still be cut out to make room for faster-growing trees. The problem therefore lies primarily in the hands of the hickory users, and it will be necessary to secure closer cooperation among them through such organizations, for instance, as the National Hickory Association.

ECONOMIC MEANS.

For the prevention of waste, the following recommendations are made:

1. Grading rules should be revised to stop unjust discrimination against heartwood and birdpecks. This will do away with most of the waste, and if such new rules are put in operation and made effective, they should reduce the annual cut at least 15 per cent. Fortunately, steps have already been taken toward this end by the National Hickory Association.

2. Overproduction should be prevented, because hickory wood is so quickly attacked by borers that material which is not immediately disposed of is almost invariably subject to heavy loss. Manufacturers' associations have already taken some action along this line.

3. There should be less specialization in the manufacture of hickory. For instance, skewers, small handles, and dowel pins could and should be manufactured only as by-products in the making of spokes, ax handles, rims, and shafts, and spokes and handles can be made in connection with rim or pole and shaft operations. This will not only permit a closer utilization of material at the mill but will make it possible to utilize more closely in the woods. Economy of this sort is now practiced by many companies, but it should be carried much further. The best example of the wastefulness of the present methods is the riving out of spoke billets and handle blanks in the woods. The superior quality of rived billets and spokes is due largely to the fact that only the best material is taken and the rest is left or, perhaps, sold as firewood. Sawing should be substituted for riving, because, by sawing, many more—often twice as many—spokes and handles can be gotten out, and much of the present waste can be utilized for hammer and hatchet handles, skewers, dowel pins, and other uses.

To place the hickories upon an equal commercial footing with other trees, two measures are imperative. In the first place, a cubic foot log rule should replace the inaccurate and unjust rules now in use. In buying and selling any commodity, a standard of measurement is fair only when both parties to the transaction understand just what it means, but the hickory rules now in use confuse even the experienced lumberman, to say nothing of the inexperienced woodlot owner. The cubic measure, used everywhere in Europe and in some places in this country, is much more accurate and satisfactory for general use than the board foot measure, and it is especially applicable in the case of hickory, because it is not usually cut into boards or planks but into piece stock. The adoption of the rule given in Table 13, which applies especially to the hickories, is therefore strongly urged.

In the second place, there should be a general advance in prices to permit of higher stumpage values. It is inevitable that such an advance must come, and the sooner the advance begins and the attention of forest owners is drawn to the value of hickory, the less danger there will be of a serious shortage with accompanying high prices and general inconvenience. Higher prices, moreover, will not only encourage the care of the hickory in the forest, but will also be a most effective means of reducing waste and forcing closer utilization.

SILVICULTURAL MEANS.

To produce spoke and handle material, which takes more than half the annual cut of hickory, no method seems better than reproduction by sprouts. Sprouts grow faster than seedlings for the first fifty or sixty years, and produce heavier yields per acre; where sprout reproduction is at all successful it is less uncertain than seedling reproduction.

A simple clear-cutting for coppice growth, which can be used with oak and chestnut, will not, however, apply to hickories as they occur in mixed stands, because faster-growing species invariably outstrip and suppress the hickories so that they appear only on the edges or in the openings of such mixed stands. But there are many old fields and pastures, especially in the Ohio Valley, which are coming up to pure stands of hickory, and there the coppice method could be applied successfully. Since the sprouting capacity falls off very rapidly as the tree grows older, the cutting should begin as soon as the trees are large enough to use, which will be when they are from 8 to 9 inches in diameter and from 40 to 50 years old. The stand may then be cut clear.

Pure stands, however, are uncommon and it will often be advisable to plant hickory with the idea of ultimately managing it as a sprout

forest. Because of the danger from squirrels and mice, fall planting should not be attempted. The nuts should be kept over winter between layers of sand and planted in the spring, and since the long taproot makes transplating impracticable, the nuts should be planted directly in the permanent site, and never in a nursery. The spacing should be about 5 by 5 feet and two or perhaps three nuts should be placed in each spot about 2 inches under the surface, or it might be well to try a group mixture with a light-seeding species, such as white ash.

Care should be taken to plant only those species which are suited to the soil conditions. On exposed situations or on dry or sandy soils pignut is to be preferred, and even that demands a moderate amount of fertility to produce timber of good quality. On moist or wet soils big shellbark should be selected, and on fresh, fertile soils either shagbark or pignut. The latter furnishes the better grade of wood, but the value of the nuts is a consideration in favor of the former. A plantation of shagbark would begin to bear about the thirtieth year, and from then on it should average scarcely less than 10 bushels of nuts per acre. Bitternut, nutmeg hickory, and water hickory are inferior species and should not be planted; mockernut has nothing to commend it over pignut; and pecan is valuable chiefly only for its nuts.

To secure the normally rapid growth essential to the production of strong wood, the stand should not be allowed to become overcrowded. Thinning should begin about the twenty-fifth year. The crooked or defective trees and those which are being crowded and have not room enough to grow should be removed. This will yield from 2 to 3 cords of firewood and will leave, perhaps, 800 trees to the acre. Eight or ten years later the thinning may be repeated. This should yield about 3 cords of firewood and perhaps a few handle bolts, and will leave, perhaps, 400 trees to the acre. At the end of the next ten years, if the soil is fertile, it is barely possible that the stand may be ready to cut, but since seedling stands grow more slowly than sprout stands, it will usually be necessary to wait an additional ten years before cutting. In this case another ten-year thinning should be made, which should leave about 200 trees to the acre, and should yield, perhaps, a cord of spoke or handle bolts and 2 or 3 cords of firewood. By the fiftieth or sixtieth year the stand should be merchantable, and should then be cut and managed as a sprout forest.

In uneven-aged, mixed forest, where the clear-cutting sprout method can not be used, hickory can readily be reproduced by the selection system. In fairly open mixed stands hickory reproduces well and forms clean, straight stems under the partial shade of older

trees and produces the heaviest, strongest, and toughest wood. Since the best material is obtained from thrifty trees, the object of management should be to make the hickories clean themselves early, and then, after sufficient clear length has been formed, to make them grow fast. For this purpose the ax should be used freely wherever it is possible to utilize the thinnings. Such inferior species as beech, maple, black oak, elm, and bitternut, as well as defective trees of all species, should be cut out wherever they interfere with the shagbarks, pignuts, big shellbarks, and mockernuts. These thinnings should be repeated every eight to ten years until the forest assumes the form of a rather open upper story of thrifty hickory, white oak, black walnut, yellow poplar, and ash, with an understory of young growth, largely young hickory. Intelligent cutting thus can increase greatly the proportion of hickory in the forest and can improve the quality of the wood by hastening its growth. In such a forest the hickories finally should be cut when they have reached a diameter of about 12 inches. At this diameter, on moderately good soil, they will be increasing in volume at the rate of about 4 per cent a year; at 14 inches the increase is about 3 per cent, and at 16 inches 2½ per cent.

It will not be wise, however, to establish a hard and fast diameter limit, because the condition in which the stand is to be left must be taken into consideration. Smaller trees may be cut wherever there is promising young growth to take their places. If it is desired to increase still further the proportion of hickories in the stand, the trees should be left longer, and they must also be left longer where the other species are cut to a large diameter limit or where it is impossible to give the stand much attention. In mountainous and inaccessible regions, therefore, where oak is cut to a diameter limit of 18 or 20 inches and inferior species and defective trees are usually left, the hickories should hardly be cut to a smaller diameter than 15 inches.

Particular attention should be given to protecting the young growth. Woodlot owners should make special provision for this in the contracts for the sale of stumpage. The cutting of hoop poles should be discouraged, and it is a fortunate fact that the business is now becoming unprofitable. The straightest, cleanest saplings invariably are cut, and scrubby, knotty, and crooked specimens are left to form the basis of the future crop. Pasturing should be prohibited, and every means possible should be taken to guard against fire.

SUMMARY.

On the economic side the following facts are apparent: Hickory has a number of important special uses for which no satisfactory substitute is known, and the hickory of commerce is derived almost

entirely from the true hickories, pignut, shagbark, mockernut, and big shellbark. The supply of large hickory, which hitherto has been depended on, is rapidly approaching exhaustion, and it will soon be necessary to depend entirely upon the second growth. Since the hickory-producing woodland is owned mainly in small holdings, such as farmers' woodlots, the perpetuation of the supply depends largely on the care of these woodlots by individuals. Stumpage prices are comparatively low, and the economic position of the tree is still further lowered by unjust and inaccurate log rules. Of the merchantable hickory cut each year fully 40 per cent is wasted.

From the silvicultural standpoint, as compared with other important timber trees, the hickories are slow growing, produce a low yield per acre, and are exacting in their soil and moisture requirements; but they are long-lived, tolerant of shade, and there is good natural reproduction both from seed and from sprout. The wood produced is superior in toughness and strength to any other commercial wood. Among the different species pignut is not only best because it is best adapted to forest management, but also because of the value of its wood, though shagbark is to be preferred where the value of the nuts is an important consideration. Big shellbark is a good tree for moist situations; mockernut has nothing to commend it over pignut. The pecan hickories grow faster than the true hickories, but their wood is generally inferior. This inferiority is not very great, however, and the best bitternut or nutmeg hickory is superior to the average of shagbark or pignut.

There is reason to expect that hickory will soon bring more adequate returns, and it should rank among the important timber trees of the managed woodlot. Planting will in many cases be worth while, and sprout reproduction can be successfully practiced in the case of pure stands. The most important method, however, will be the growing of hickory in uneven-aged, mixed stands, in which the reproduction of hickory is already very good. Given its proper place in the forest, there should be no difficulty in maintaining the supply of hickory, and, under management which will eliminate inferior species and trees, secure thrifty growth, and harvest the crop before it is overmature, the quality of the yield will be greatly improved, and the quantity increased.

The technical value of the wood differs greatly within the same species under similar silvicultural conditions, and even within an individual tree. Often these differences can not be accounted for, but in general the wood put on by a thrifty tree during the period of its greatest vigor is the best, and the wood from the butt cuts is superior to that from the upper cuts. Within the limits of normal growth the width of the rings is not a measure of the technical value of the wood,

and for thrifty trees of the same age there are no differences in value according to geographic regions or local soil conditions. Strength and toughness are not affected by the change from sapwood to heartwood. The best criterion of the value of the wood is its weight.

To help prevent shortage in the supply, hickory users should take action to prevent waste through placing red hickory upon an equal footing with the white, to secure economy in usage through closer cooperation, and to improve the economic position of the tree through the adoption of a just log measure.

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A PLANTATION OF BIG SHELLBARK 27 YEARS OLD.

[The spacing was originally 4 by 4 feet, but the stand has been thinned. Champaign County, Ill.]

FIG. 1.—REPRODUCTION OF HICKORY IN A FIELD CUT OVER FOUR YEARS AGO AND PASTURED SEVERELY BY SHEEP, CATTLE, AND HORSES.

[Other species except hickory have been killed back. This illustrates strikingly the persistent sprouting capacity of hickory and its relative immunity from browsing by cattle. Defiance County, Ohio.]

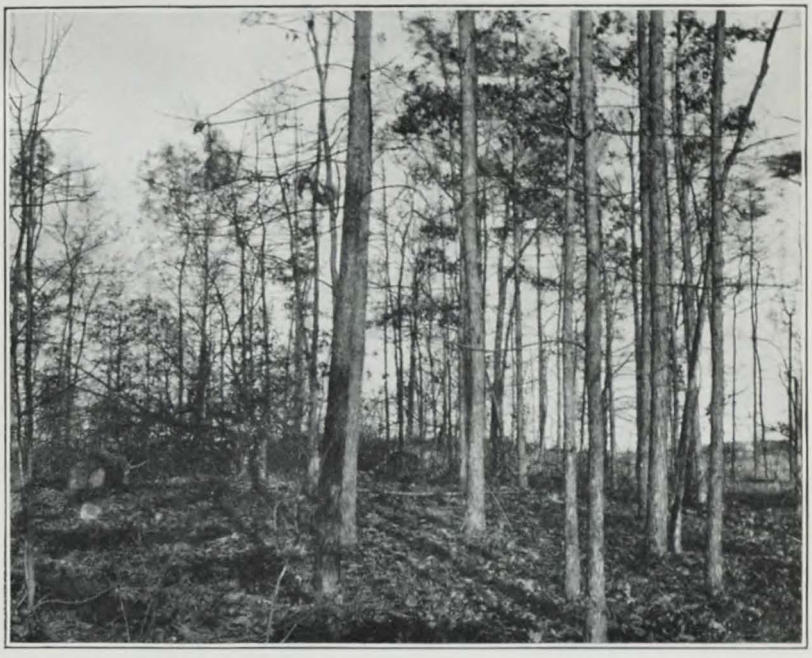

FIG. 2.—A YOUNG STAND OF HICKORY AFTER THE MORE MATURE TREES HAVE BEEN CUT.

[This leaves groups of young trees to take the place of the old ones, and is the right way to raise hickory. Fulton County, Ohio.]